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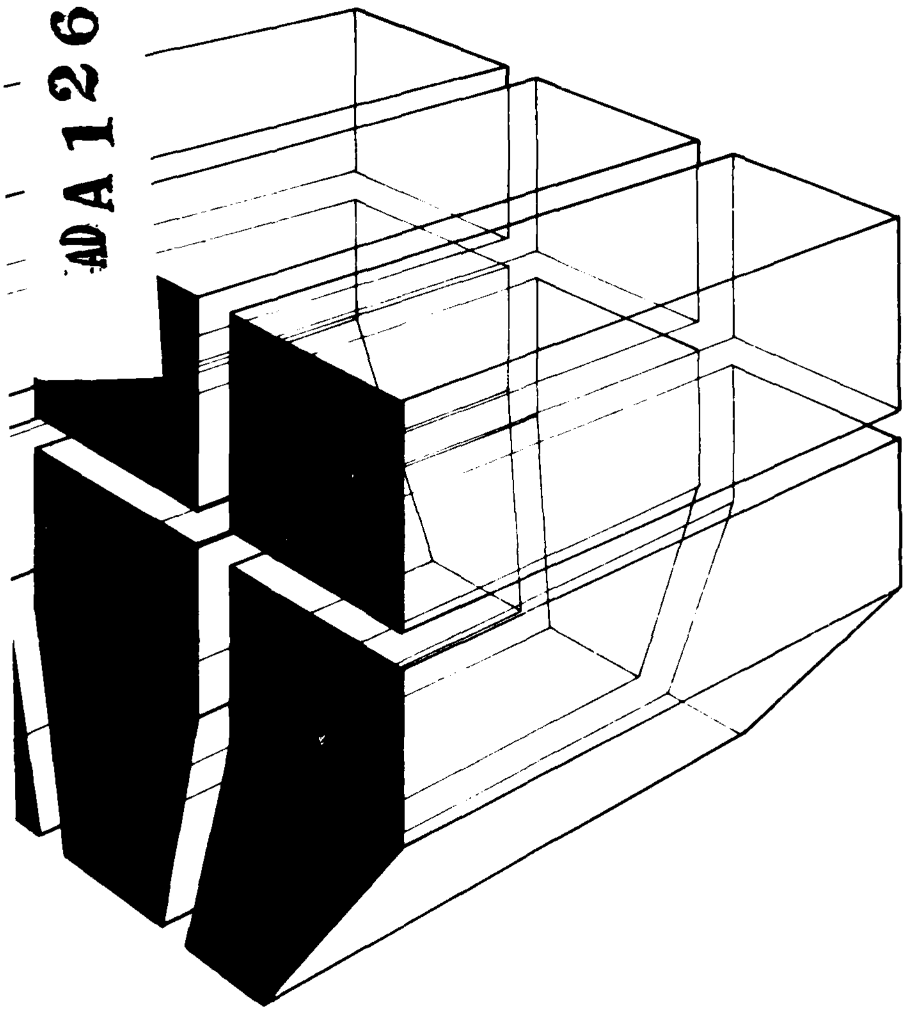
# AN OVERVIEW OF THE ECOLOGICAL EFFECTS OF TRACKED VEHICLES ON MAJOR U.S. ARMY INSTALLATIONS



by
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Various levels of field studies were done on 12 U.S. Army Training and Doctrine Command (TRADOC) and U.S. Army Forces Command (FORSCOM) installations to provide a general overview of ecological disturbance caused by U.S. Army tactical vehicle training. Detailed quantitative data were obtained from Forts Polk, Knox, Hood, and Lewis; supplementary semi-quantitative and qualitative studies were done at Forts Benning, Bliss, Carson, Drum, Irwin, Riley, and Stewart, and at Yakima Firing Range.

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The overall results varied, depending on the installation and ecosystem studied. The following results were obtained:

1. Mammal populations show a change in species composition, with increases in white-footed mice and decreases in shrews, wood rats, voles, moles, squirrels, and chipmunks. Heteromyid rodents (kangaroo mice and rats) remain virtually unchanged. Biomass reductions somtimes occur, depending on the species composition of the original population. On some severely impacted sites, populations of all species are reduced.

2. Bird populations generally show significant biomass reduction. The concurrent change in diversity is not wholly evident, since numbers of species remain about the same. The important change is in species replacement. In most training areas and ecosystems, species which are secretive or highly sensitive to disturbance are replaced by less sensitive species; many of these are clearly disturbed-site, early-successional, or introduced species.

3. Plant populations are drastically reduced and altered due mainly to: loss during clearing/preparation operations; physical contact with training vehicles, which either kills the plant or causes injury great enough to kill it; and root damage, reduced seed germination, or reduced seedling growth due to soil compaction. Climax species tend to be replaced by early successional species, and, to varying degrees, by a reversal of the successional process.

4. Soil problems are universal due to increased erosion caused by compaction of the lower horizons, loosening of the upper horizons, and removal of vegetative cover. The extent of these problems varies, depending on factors such as slope, soil type, depth to bedrock, rainfall, and vegetative cover.

FOREWORD

This investigation was performed for the Assistant Chief of Engineers by the Environmental Division (EN) of the U.S. Army Construction Engineering Research Laboratory (CERL). The work was done under Project 4A161102AT23, "Basic Research in Military Construction," Technical Area C, "Environmental Quality," Work Unit 001, "Interdependence of Elements in Ecological Systems"; and Project 4A762720A896, "Environmental Quality Technology," Technical Area B, "Source Reduction Control and Treatment," Work Unit 036, "Training Area Maintenance." The Technical Monitor was Mr. Donald Bandel, DAEN-ZCF-B.

The following persons made major contributions to this study: S. Apfelbaum, A. Haney, F. L. Johnson, R. E. Riggins, G. D. Schnell, M. C. Severinghaus, and O. Soule. Work by the following people is also gratefully acknowledged: R. Blodgett, F. Briuer, J. Caldwell, J. Grafton, D. Palmer, D. Roldan, D. Strimel, C. Divinyi, J. Metcalf, J. Brandt, K. von Finger, T. Prior, C. Williams, R. Petri, R. Pierce, S. Miller, S. Clinger, A. Bowman, D. Kiefer, R. Moore, and E. Anderson. Dr. R. K. Jain is Chief of EN.

COL Louis J. Circeo is Commander and Director of CERL, and Dr. L. R. Shaffer is Technical Director.

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# 1 INTRODUCTION

## Background

Army programs and activities often affect or have the potential to affect the natural environment. Recent legislative trends in environmental impact analysis require quantification of impact estimates. Thus, there is a need to establish cause/effect relationships between Army activities and the impacts these activities have on the environment. Tracked vehicle use is an essential part of the training programs at many Army installations. These vehicles can drastically alter an installation's soil structure, vegetation, and wildlife habitat and thus adversely affect the overall natural environment. Knowledge about these environmental impacts and their short- and long-term effects will help Army personnel plan training programs that will minimize adverse effects on the local ecology.

## Objective

The objective of this report is to describe impacts of tracked vehicle training maneuvers on the natural environment.

## Approach

Field studies were conducted at selected sites on 12 U.S. Army Training and Doctrine Command (TRADOC) and Forces Command (FORSCOM) installations to obtain information on ecological disturbances caused by tracked vehicle training. Data were obtained for small mammals, birds, vegetation, and soils. These data were analyzed to determine the general impacts caused by tracked vehicles on the environment.

## Mode of Technology Transfer

The information in this report will be used as background to develop sound maintenance procedures for tracked vehicle training that will insure realistic, usable training/maneuver areas for the Army. The training area maintenance procedures will be released as a Technical Manual.

## 2 THE INSTALLATIONS

The 12 installations studied during this investigation are not the Army's only tracked vehicle training sites; however, they do represent a broad range of physiographic-ecological-climatic conditions under which tracked vehicle training occurs. Also, they represent a range of different types and levels of tracked vehicle training programs. This chapter describes the physical circumstances and the tracked vehicle training programs of each installation.

### Physical Circumstances

Table 1 summarizes information about the physical regions for each installation. Figure 1 shows each installation's location.

#### *Fort Benning*

Fort Benning occupies parts of Chattahoochee and Muscogee Counties in Georgia and part of Russell County in Alabama. The installation includes 736 $km^2$, of which a small segment (less than 50 $km^2$) is in Alabama, separated from the main post by the Chattahoochee River. The main cantonment is on the Georgia side of the river, just a few kilometers southeast of the City of Columbus.

The northern boundary of the installation, in Muscogee County, runs along the southern limit of the lower Piedmont; however, Fort Benning lands are almost entirely within the upper coastal plain, along an area known as the Fall Line Sandhills. The northern and eastern parts of the post are characterized by hills and ridges, with deep, sandy soils. High elevations are more than 200 m above sea level at some points. However, in the south-central and southwestern parts of the post, especially in the flood plains of the Chattahoochee River and the Upatoi and Ochillee Creeks, the lands are gently rolling to flat, and the soils are clay sands and silts. Along the Chattahoochee River, elevations fall below 60 m.

Woodlands cover more than 70 percent of the post. Native pines include longleaf, loblolly, and shortleaf; there are also planted stands of slash pine. Turkey, bluejack, and blackjack oaks are also common in the upland, while blackgum, sweet gum, water oak, tupelo, swamp oak, and sweetbay occur in the lowland forests. Most of Fort Benning's timber management program involves selective harvesting and replanting of pine species.

The climate at Fort Benning is typical of the humid southeastern United States. Winters are mild, and summers are long and hot. Precipitation averages 1219 mm (48 in.) per year, with March and July the peak rainfall months. Usually, there is a small amount of snowfall each winter, although the severity of winter storms varies significantly from year to year. Winds vary from season to season, prevailing from the north from August to March, from the south in April, and from the west from May to July.

Fort Benning has been an infantry training center since it was created in 1918 on a former plantation site south of Columbus. Current units include the Infantry School, the Infantry Center, the 197th Infantry Brigade, the 34th

Table 1

Twelve Installations -- Land Types and Land Uses

| Installation | Physical Regions | Land Surface Forms | Potential Natural Vegetation | Land Use Regions |
|---|---|---|---|---|
| Benning | Gulf-Atlantic coastal plain piedmont to coastal plain | Irregular plains | Oak-hickory-pine forest (*Quercus-Carya-Pinus*) | Cropland with pasture, woodland, and forest (grazed) |
| Bliss | Basin and range; Chihuahuan desert | Plains with high mountains | Grama-tobosa shrubsteppe (*Bouteloua-Hilaria-Larrea*) to trans-pecos shrub-savannah (*Flourensia-Larrea*) | Desert shrubland (grazed) |
| Carson | Rocky Mountain piedmont mountains to great plains | High mountains to tablelands | Grama-buffalo grass (*Bouteloua-Buchloe*), juniper woodland (*Juniperus-Pinus*), and pine-douglas fir forest (*Pinus-Pseudotsuga*) | Subhumid grassland and semi-arid grazing land to forest and woodland |
| Drum | Adirondack highlands to central lowlands | Irregular plains to plains with high hills | Northern hardwoods (*Acer-Betula-Fagus-Tsuga*) Beech-maple (*Fugus-Acer*) spruce (*Picea*) | Cropland with pasture, forest, and woodland (grazed) |
| Knox | Eastern interior uplands and basins | Open hills | Oak-hickory (*Quercys-Carya*) and beech-maple (*Fagus-Acer*) | Cropland with pasture and woodland |
| Hood | Mid-continent plains and escarpments | Tablelands | Blackland prairie (*Andropogon-Sipta*) and juniper-oak savannah (*Andropogon-Quercus-Juniperus*) | Cropland with grazed woodland and grassland |
| Irwin | Basin and range; Mohave desert | Plains with low to high mountains | Creosote bush (*Larrea*) | Desert shrubland (mostly ungrazed) |
| Lewis | Puget-Wilamette lowland, Pacific border | Tablelands to open hills | Cedar-hemlock-douglas fir (*Thuja-Tsuga-Pseudotsuga*) | Woodland and forest with cropland and pasture |
| Polk | Gulf-Atlantic coastal plain | Irregular plains | Oak-hickory-pine (*Quercus-Carya-Pinus*) | Forest and woodland (grazed) |
| Riley | Mid-continent plains and escarpments | Open hills to irregular plains | Bluestem prairie (*Andropogon-Panicum-Sorghastrum*) | Mostly cropland to cropland with grazing to grassland (grazed) |
| Stewart | Gulf-Atlantic coastal plain and coastal flats | Flat plain | Southern mixed forest (*Querus-Fagus-Liquidambar-Magnolia-Pinus*) | Forest, pasture, cropland |
| Yakima | Cascade-Klamath-Sierra Nevada ranges, Columbia basin | Open low mountains | Sagebrush steppe (*Artemisia-Agropyron*) | Semi-arid grazing land to cropland with grazing |

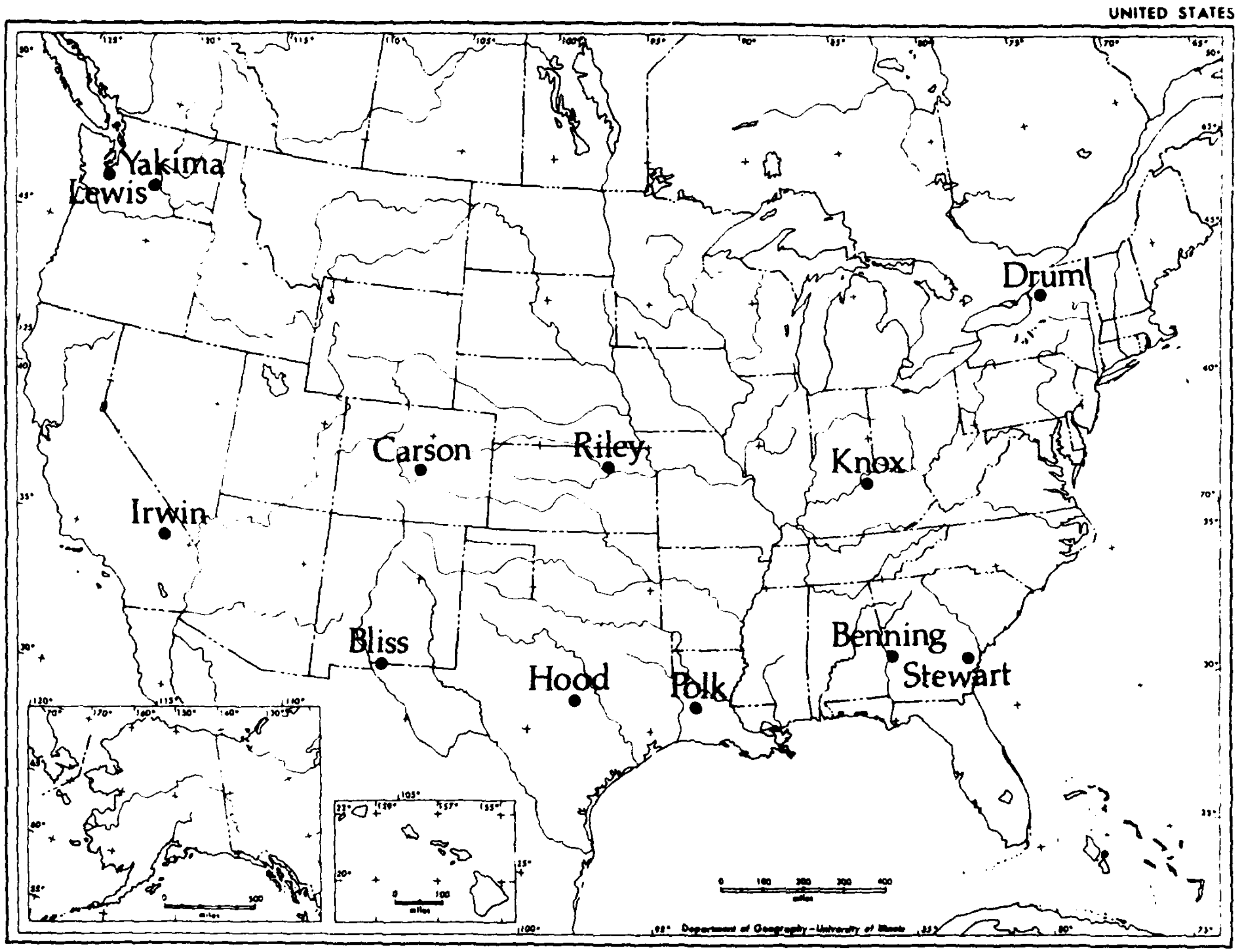


Figure 1.  Locations of the installations studied.

Medical Battalion, and the 36th Engineering Group. While most training and troops at Fort Benning are infantry oriented, several units have a high level of tracked vehicle use. The Infantry School makes intensive use of armored personnel carriers, which causes significant tracked vehicle damage in certain areas.

Tracked vehicle activity occurs in locations throughout the post; however, it is most extensive on the western side, along sand ridges forested by longleaf pine and turkey oak with frequent areas of sparse tree cover and open fields. Ground vegetation in these areas usually remains in early successional stages due to the continuous mechanical disturbance.

*Fort Bliss*

Fort Bliss is located in El Paso County in western Texas, and Don Ana and Otero Counties in south-central New Mexico, within the range of the Chihuahuan desert, just east and north of El Paso. The installation is very large (4518.6 $km^2$); however, more than 3000 $km^2$ of this land are used as firing ranges, including the immense McGregor Guided Missile Range. More than 1000 $km^2$ are used regularly for maneuvers.

The terrain on the installation itself is relatively flat, occupying the north-south oriented Tularoosa Valley and varying from 1160 to 1300 m above sea level; however, the Franklin and Organ Mountains lie just to the west, and the Heuco Mountains and the Otera Mesa lie to the east. Shrubs dominate the Chihuahuan desert; much of Fort Bliss is characterized by mesquite shrubs atop dunes in coarse, sandy soils. Gravelly areas and alluvial fans are dominated by unduned creosote bush landscapes; washes are typically lined with apache plume and desert willow. Grasses increase toward the Otera Mesa, and the soil has more clay and silt. The limited rains are concentrated during late summer; flowering annuals are most evident at this time.

The climate at Fort Bliss is typical of the arid southwest, with low humidity, low rainfall, and abundant sunshine. The annual rainfall, averaging 200 mm (7.9 in.) occurs generally in thunderstorms during the summer. Temperatures are very warm between April and September, but diurnal variations are high and summer nights are usually cool. Winter days are mild, but night temperatures often drop below freezing, and occasionally light snow falls. Winds are highest during March and April, and, because ground vegetation is sparse, there are frequent dust and sandstorms in the early spring.[1]

Fort Bliss was an important cavalry outpost in frontier times. During World War II, the installation became the home of the U.S. Army Air Defense Center. The 3rd Armored Cavalry Regiment is also stationed at Bliss. This unit uses about 750 tracked vehicles in extensive cross-country maneuvers. Much of the cross-country traffic weaves between the mesquite dunes, which are tall enough to provide excellent cover in several areas. Although traffic is heavy in some areas, the high winds of west Texas frequently erase evidence of tracks from the sandy soil within a few days.

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[1] Fort Bliss, Texas, Terrain Analysis (Engineering Topographic Laboratory [ETL], 1978), p 51.

*Fort Carson*

Fort Carson is located along the Rocky Mountain Front Range Corridor between Colorado Springs and Pueblo in semi-arid, south-central Colorado. The main cantonment is about 13 km south of Colorado Springs. Most of the installation, which includes more than 550 $km^2$, is in El Paso County; however, the post boundaries extend over 38 km north-south and stretch south into parts of Pueblo and Fremont Counties. Several areas have been placed off-limits for restoration due to the stress of training (and grazing) activities; thus, only about 238 $km^2$ are available for maneuvers. However, Fort Carson is now expanding to include a large area of land to the east and south of the main post.

The eastern portion of the post has gently to moderately sloping grasslands with relatively low relief; the western portion abuts the Rocky Mountains and has wooded foothills, steep and rocky slopes, and higher elevations. The elevation varies from 2120 m along the west side to 1560 m in the southeast. Streams draining Fort Carson generally flow from the northwest to the southeast, joining the south-flowing Fountain Creek just east of the installation boundary. These on-post streams are intermittent, containing water during snowmelt and after rainfall.

Soils in the post's eastern and northern sections are generally developed from upland clayey materials weathered from shale; they support plains grasses such as blue grama, big bluestem, and western wheatgrass. Toward the west, many of the soils are derived from sandstone and are deeper and more well-drained; they support foothill grasses, shrubs, and trees. Colorado pinyon and one-seed juniper are the most common trees, but Ponderosa pine and Rocky Mountain juniper also occur in patches. Alluvial soils along the streambeds support both grasses and deciduous woodlands, with willow and cottonwood stands in some areas. Soils are thin over much of the installation; both sheet and gully erosion are major problems.

At its high elevation, Fort Carson has cool summers and cold winters. Located on the lee side of the Rockies, the post receives relatively low precipitation, averaging 360 mm (14.2 in.) per year; more than 80 percent occurs from April to September. Snowfall is heavy -- about 1000 mm (39 in.) per year -- but snow moisture content is usually low. Prevailing winds are from the north; however, in the winter, chinook winds descend from the eastern slopes of the mountains and moderate the cold. The highest winds occur in the spring.

During the 1960s, Fort Carson was the home of the 5th Infantry Division, but in 1970, this unit was replaced by the 4th Infantry Division (Mechanized). This Division, which includes three full infantry brigades and several specialized battalions, is the largest mechanized infantry division in the United States. These units use almost 1000 tracked vehicles during regular training activities.

*Fort Drum*

Fort Drum, located in Jefferson and Lewis Counties in upstate New York, about 32 km east of Lake Ontario, includes more than 43_ km$^2$. The glaciated landscape has diverse geology, soils, topography, and vegetation. Toward the Adirondack Mountain highlands to the north and east, the lands become hilly, with frequent rock outcrops, numerous lakes, and dense forests of mixed coniferous and deciduous trees. To the west and south, lands are more typically flat, with marshes and swamps, and areas of more open forest and grassland. Soils are very sandy toward the south, and more clayey to the west. In wet weather, these clayey soils impede tracked vehicles.

Fort Drum's climate is characterized by long, cold winters and short, warm summers. Precipitation is well distributed throughout the year, with rainfall occurring normally in all warmer months and heavy snowfall, averaging 2900 mm (114 in.), in the winter. Temperatures can be very cold during the winter, with wind chill occasionally falling below -30°C. In the summer, day temperatures can be hot (the July record is 37.7°C), but the nights are cool. Winds are normally moderate, but can be high during summer thunderstorms or winter snowstorms.[2]

No regular troops are assigned to Fort Drum; however, the installation is used extensively by National Guard and Reserve units from several states. Also, Fort Drum is the only installation in the contiguous 48 states whose climate is suitable for practicing ground combat under cold weather conditions. Recently, several large-scale mid-winter exercises at Fort Drum have included considerable tracked vehicle traffic.

*Fort Hood*

Fort Hood is in Bell and Coryll Counties, central Texas, 98 km north of Austin and 63 km southwest of Waco. The installation covers 878 km$^2$; of this, 35 to 40 percent is grassland and savannah, and 55 to 60 percent is woodland and scrub. The grasslands generally occupy level to gently rolling topography; major species include little bluestem, sideoats grama, broomweeds, triple-awn, and seep muhly. Texas oak, live oak, and rock cedar dominate the hillside woodlands; in the bottom land, Texas ash, cedar elm, netleaf hackberry, slippery elm, and Mexican plum are major species. Soils at Fort Hood are generally shallow and rocky. In many areas, tracked vehicle traffic has worn the thin soils down to limestone bedrock.

Fort Hood occupies a transitional zone between the humid, subtropical region of east Texas and the semi-arid region to the west. The climate is continental, with extreme and rapid variations in temperature. Winters are generally mild, with brief cold spells and some nights below freezing. Snow is rare and does not accumulate. Summers are hot and long, with mid-day temperatures often higher than 35°C. Precipitation occurs throughout the year, but is lowest in July and August. Storms are most frequent in March and April, and these are also the months of strongest winds.[3]

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[2] Fort Drum, New York, Terrain Analysis (ETL, 1977), p 23.
[3] Environmental Impact Statement, General Mission, Fort Hood, Texas (Fort Hood, 1979).

Fort Hood is the home of both the 1st Cavalry Division and the 2nd Armored Division. With an authorized active Army strength of about 46,000, it has more troops than any other U.S. military installation. These troops use about 2500 tracked vehicles for training. The impact of extensive cross-country traffic is evident throughout the maneuver areas, especially along the western side.

*Fort Irwin*

Fort Irwin is located in the Mohave Desert in southeastern California, about midway between Los Angeles and Las Vegas. The installation, which includes more than 2600 $km^2$, lies entirely within the vast San Bernardino County, surrounded by Federal lands, and remote from cities. The nearest community is Barstow, about 60 km to the southwest.

Like Fort Bliss, Fort Irwin occurs in the vast Basin and Range Physiographic Province. The installation has numerous mountain ranges which surround closed drainage basins; most of these basins include intermittent lakes, called playas. Two of the major on-post ranges -- the Granite and Tiefort Mountains -- are primarily granitic intrusions; however, the Avawatz Mountains, which separate Fort Irwin from Death Valley National Monument, are precambrian metamorphic rocks. Other on-post ranges are volcanic in origin. While there are no perennial water bodies, there are several springs and seeps along the base of these mountain ranges. Sparsely vegetated soils are silty, sandy gravels and silty gravels; years of wind and water erosion have removed the fine particles from the surface, leaving a residual layer of coarse particles, known as desert pavement.

The climate is very arid; annual precipitation averages about 40 mm (1.6 in.) and generally occurs from December to February. Summers are very hot and winters mild, but diurnal fluctuations may be 15° to 30°C throughout the year. Winds are frequently strong, especially in the winter.

About 85 percent of the installation lands support a creosote bush scrub community, which dominates the basins, hillsides, and lower mountains; burroweed, spiny senna, and cheesebush are sometimes codominant. At higher elevations, there are some stands of Joshua Tree woodlands, while shadescale scrub occurs in the washes and on alkaline sites; saltbush species occur around the edge of the barren playas. Since rough terrain limits vehicle access to about 40 percent of the installation lands, most cross-country traffic occurs amidst the creosote bush scrub.

The installation was opened in 1941 as the Mohave Anti-Aircraft Range. After World War II, it was closed and reopened several times; most recently, it has been used extensively by the National Guard and the Reserves. Fort Irwin has more than 1670 $km^2$ of maneuver areas, which provide adequate space for a total combat environment for large units; therefore, it has been designated for use as a national training center. Troops from installations throughout the country travel to Irwin to conduct large-unit-type exercises lasting several weeks. There are now about 700 tracked vehicles on-post, and extensive cross-country traffic occurs throughout the year.

*Fort Knox*

Fort Knox, located along the Ohio River about 48 km southwest of Louisville, occupies 446.6 $km^2$ of forested, rolling hills. It occupies parts of three counties: Bullitt, Hardin, and Meade. Oaks and hickories dominate the forests on the uplands and exposed slopes; sugar maple and tulip poplar dominate low areas and sheltered slopes. Important edge and understory tree species include eastern red cedar, persimmon, sassafras, and dogwood. The herbaceous understory is dense and viney.

The climate at Fort Knox is humid continental, with four distinct seasons. Summers are hot and humid, while winters are relatively mild. Winter snowfall averages 399. mm (15.7 in.), and annual precipitation is 1095 mm (43.1 in.). This precipitation occurs throughout the year, although thunderstorms, moving up the Gulf of Mexico, usually occur in spring and summer.[4]

In the humid Kentucky climate, some of the limestone-based soils have developed characteristic features of Karst topography, such as sink-holes, discontinuous surface drainage, and well-developed subsurface drainage. This topography is most evident along the Otter Creek watershed, where much of the cross-country tracked vehicle activity has occurred and where CERL conducted a spring-summer study in 1978.[5] Soils in this area are fine-grained silts and clays and present serious erosion problems.

Since the 1930s, Fort Knox has been a center for U.S. Army tracked vehicle training. The installation is the home of the U.S. Army Armor Training Center and the 194th Armored Brigade. These units have about 1000 tracked vehicles in active use. Various types of tracked vehicles have crossed the hilly lands of Fort Knox for several decades, and their impact has been significant.

*Fort Lewis*

Fort Lewis, located in west-central Washington, borders the southern tip of Puget Sound; it is 24 km east of Olympia, 10 km west of Tacoma, and 80 km south of Seattle. The irregularly shaped post occupies portions of both Pierce and Thurston counties. The Cascade Mountains are just 70 km to the east, and the Olympic Mountains are about 85 km northwest; however, the installation itself is on 348 $km^2$ of gently rolling glacial outwash plain. About 80 percent of the land is covered by a dense forest dominated by Douglas fir. There are also many scattered lakes, scattered prairie areas, and a deciduous forest along the terraces of the Nisqually River. This river, which drains the glaciated slopes of Mount Rainier, divides the installation into northeastern and southwestern sectors, flowing north into the Sound.

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[4] Fort Knox, Kentucky, Terrain Analysis (ETL, 1978), p 27.

[5] W. D. Severinghaus, R. E. Riggins, and W. D. Goran, Effects of Tracked Vehicle Activity on Terrestrial Mammals, Birds, and Vegetation at Fort Knox, KY, Special Report N-77/ADA073782 (U.S. Army Construction Engineering Research Laboratory [CERL], 1979); W. D. Severinghaus, R. E. Riggins, and W. D. Goran, "Effects of Tracked Vehicle Activity on Terrestrial Mammals and Birds at Fort Knox, Kentucky," Trans. Kent. Acad. Sci. (1980), 41 (1-2); pp 15-26.

Except for the Nisqually, surface drainage channels are poorly defined, with numerous shallow lakes and marshes. The west-flowing Muck Creek, which crosses portions of two on-post prairies, is a salmon spawning ground. Because of the density of the fir forest, much of the cross-county tracked vehicle traffic occurs on the larger prairie sites. Despite the mesic climate, upland positions on these prairies, which overlay moraine deposits of stones and gravel, are often dry and excessively drained.

The Fort Lewis area has relatively warm, dry summers and mild, wet winters. Total annual precipitation averages 1043 mm (41 in.), including 2319 m (9.4 in.) of snowfall. Only about one-sixth of the total precipitation falls between May and September, and there are usually dry spells with high fire danger during the summer. Morning fog frequently occurs at Fort Lewis, especially in the spring.[6]

Since 1972, the 9th Infantry Division has been stationed at Fort Lewis, which was established as a U.S. military installation in 1917. Because training is infantry oriented, tracked vehicle use is not as extensive as at posts like Forts Hood and Knox. There are about 375 tracked vehicles in use at both Lewis and its subinstallation, the Yakima Firing Center. However, because the dense coniferous forests at Lewis are generally impenetrable to cross-country traffic, the limited prairie areas receive considerable use. Also, if the 9th Infantry Division is converted to mechanized infantry, tracked vehicle activity is predicted to increase five times.

*Fort Polk*

Fort Polk and Peason Ridge Training Area are located within the Gulf Coastal Plain in west-central Louisiana, about 80 km southwest of Alexandria. The post occupies parts of Vernon, Natchitoches, and Sabine Parishes. The installation, which includes 802 $km^2$, is situated on rolling, hillocky, pine-oak forested uplands, cut through by several oak-cypress-tupelo-gum alluvial bottomlands. Sandy soils generally overlay clay subsoils and sedimentary bedrock.

Besides the main post area, which is located entirely within Vernon Parish, there are two smaller subunits of land that make up the installation -- Peason Ridge and Horse's Head. Both of these subunits are north of the main post. Peason Ridge, which straddles Vernon, Sabine, and Natchitoches Parishes, and occupies 135.5 $km^2$ is Army-owned and receives intensive training use. The terrain is more hillocky than on the main post, with some prominent ridges and a high elevation of 147 m. The Horse's Head area, just north of Peason Ridge, occupies 51.9 $km^2$ entirely in Natchitoches Parish. It is owned by the U.S. Forest Service, like the southern portion of the main post area, and receives only limited military use. While the terrain is similar to that of Peason Ridge, there are only a few small, open, grassy areas on the Horse's Head area, while there are several large open areas on Peason Ridge.

Longleaf and Loblolly Pines are the dominant trees on upland sites throughout the post. Also abundant in the area are Shortleaf Pine and Southern Red, Post, Blackjack, and Bluejack oak, as well as Sweetgum and Sassafras. Important understory species include Shining Sumac, Poison Ivy, Southern

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[6] Fort Lewis, Washington, Terrain Analysis (ETL, 1978), p 39.

Waxmyrtle, Sweetbay, Blackberry, Yaupan, and Dogwood. The lowland areas are covered with a dense hardwood forest, are often impassable, and receive little cross-country usage.

The subtropical climate at Fort Polk is characterized by long, hot summers and mild winters. Rainfall averages 1346 mm (53 in.) annually and is most abundant during the winter and spring. The driest period occurs in the autumn. Winds are generally from the south, except for winter fronts which move in from the north. Snowfall is light, and the coldest months -- December through February -- are generally mild. The summers are long, with high temperatures and humidity; showers and thundershowers from the Gulf bring occasional relief.[7]

The U.S. Army bought Fort Polk during World War II; it was an important early site for tracked vehicle training activities. The 5th Infantry Mechanized Division, which is now stationed at this installation, uses about 750 tracked vehicles in active training. Much of the cross-country activity occurs on Peason Ridge, where tracked vehicles frequently wander from the main roads and cross the open canopy areas of the pine forest. Damage to young pine trees and understory vegetation has been significant; the sandy upland soils are also easily disturbed.

*Fort Riley*

Fort Riley is situated in northeastern Kansas, just north of where the confluence of the Smoky Hill and Republican Rivers forms the east-flowing Kansas River. It occupies parts of Riley and Geary counties. Junction City, in Geary County, is just south across the confluence, and Manhattan, in Riley County, is 8 km east. Directly west is Milford Reservoir, formed by a dam on the Republican River. The installation, which occupies 408.7 $km^2$, consists roughly of 10 percent creek and river bottomland, 35 percent upland prairie, and 55 percent broken hilly country.

Bordering Fort Riley are the Flint Hills, the largest remaining area of tallgrass prairie in North America. The Flint Hills extend into the eastern portion of the installation. These hills which continue south across the Kansas River through the State of Kansas, form a distinctive landscape with long, terraced slopes. The hills are composed of limestones and shales deposited from an inland sea during the Permian Age. The uplands have shallow topsoils characterized by chert, or flint, from which the hills derive their name.

Dominant species in this tallgrass prairie include big and little bluestem and Indiangrass, with lesser amounts of switchgrass, gramas, and buffalograss. The upland ravines support a deciduous scrub community, including honey locust, sumacs, redbud, dogwood, and white mulberry. Lower down the watercourses, these species yield to bur oak and American elm; sycamore, cottonwood, chinquapin oak, green ash, and hackberry grow in the floodplain.

In the immediate Fort Riley area, the Flint Hills are dissected by numerous streams cutting down to the bottomlands of the Smoke Hill and Kansas Rivers. There are rock outcrops on some of the steeper hillsides and rock

[7] Fort Polk, Louisiana, Terrain Analysis (ETL, 1978), p 25.

escarpments along the river floodplains. North and west of the Flint Hills region is an area of undulating, upland prairie, with deeper soils and fewer rock outcrops. Elevations on-post range from a low of about 312 m in the bottomlands of the Kansas River, to hilltops on the upland prairie of just over 411 m, for a range in elevation of about 99 m.[8]

Wildcat, Sevenmile, and Threemile Creeks drain the eastern part of the installation, flowing southeast to join the Kansas River. The western parts of the installation are drained by many smaller creeks. Timber, Dry, Madison, Farnum, and Rush Creeks all empty into Milford Reservoir, while Fourmile Creek joins the Republican River downstream from the dam. All these streams normally carry water throughout the year, though there are several minor streams on the post that are intermittent.

The Fort Riley area experiences a continental climate, with summers hot and winters moderately cold. The precipitation is heaviest in early summer, with about 75 percent of the annual 838 mm (33 in.) precipitation occurring during the growing season. The summer precipitation frequently occurs as thundershowers. Winters are generally clear and dry, with snowfall averaging from 56 to 91 mm (22 to 36 in.) per year. There is slightly greater precipitation to the east than to the west in the Riley and Geary Counties area.[9]

Temperatures and humidity vary widely from season to season, with mean monthly temperatures in July and August about 27°C and about -1°C in January and February. Temperature fluctuations can reach as high as 46°C in the summer and -34°C in the winter. Generally, cold spells in the winter are of short duration, but there are periods of sustained high heat and humidity in summers. The average date of the first killing frost in the autumn is 17 October and that of the last killing frost in the spring is 22 April. Winds switch from the southwest in the summer to the north in the winter, with normal velocity from 4 to 11 miles per hour.[10]

Fort Riley was a frontier cavalry outpost established in 1853. It is now the home of the 1st Infantry Division Mechanized, with about 750 tracked vehicles in training service. Much of the installation land is devoted to firing ranges, rather than cross-country maneuvers; most traffic is to and from these ranges. Gullying problems occur along the roads and in other places receiving traffic where vehicles become mired in wet areas; species displacement occurs where traffic cuts across the prairie, as the prairie grasses yield to more impact-tolerant forbs.

*Fort Stewart*

Fort Stewart is in Georgia along the Atlantic Coastal Plain, about 65 km southwest of Savannah. It occupies parts of Liberty, Long, Bryan, Evans, and Tattnall Counties. Altogether, Fort Stewart, which is the largest U.S. Army installation east of the Mississippi, comprises 1132 $km^2$; it stretches over

8 Fort Riley, Analysis of Existing Facilities (Fort Riley, 1977), p 22.
9 Thomas B. Bragg and Lloyd C. Hulbert, "Woody Plant Invasion of Unburned Kansas Bluestem Prairie," Journal of Range Management, Vol 29, No. 1 (1977), pp 19-24.
10 Fort Riley, pp 14-15.

50 km east-west and about 28 km north-south. About 1022 $km^2$ are available for maneuvers, but much of this land is seasonally wet and untrafficable.

The installation is low and flat, rising gradually from east to west and varying in elevation from 9 to 30 m. Highest elevations occur on ridges from former coastal terraces; usually, there are low, swampy lands to the east or oceanward of each terrace. About one-third of the post is swampland. Most of the tracked vehicle cross-country activity occurs along the ridges, especially along a major ridge running north-south near the installation's western edge.

Soils at Fort Stewart, which have developed from deep, unconsolidated coastal plain deposits, are almost pure sands in the uplands and a mixture of sands and clays in the lowlands. The upland soils are excessively drained, have a low organic content, and are strongly acidic. In some lowland soils, the organic content is higher, especially along drainageways which originate in the Piedmont.

Numerous streams and rivers cross the installation lands, flowing slowly to the east and south. The lands along these streams are poorly drained and support dense, bottomland hardwoods. Lowland hardwood species include black-gum, sweetgum, sweet bay, tupelo, swamp oak, and water oak. Away from the streams, stands of longleaf and slash pine dominate, interspersed with patches of open grasslands and occasional patches of scrub oak. The installation has an extensive timber management program, and sections of the pine forests are periodically harvested and reseeded. Lands surrounding the post are also predominantly forested.

Fort Stewart's climate is humid subtropical, with short, mild winters and long, hot summers. Winter temperatures sometimes fall below freezing during the nights, but snowfall is rare. However, in summer, the combination of high humidity, high temperatures, solar radiation, and absence of air movement can create conditions stressful for active training. Precipitation averages 1270 mm; the wettest period is from June to September. However, because of the high evaporation and transpiration during this time, low-water conditions may also occur. Occasionally, the region experiences tropical storms and hurricanes, but usually winds are relatively calm.

Acquired by the Army in 1940, Fort Stewart was first used as an antiaircraft artillery training center. Tank training was added during the 1950s, and an aviation school operated at the post during the Vietnam conflict. Since 1975, the 24th Infantry Division has been stationed at Fort Stewart. During 1979 and 1980, this Division was converted from infantry to mechanized infantry; as a result, the number of tracked vehicles increased from about 850 to more than 1300.

*Yakima Firing Center*

Yakima Firing Center is located in central Washington, in the rainshadow of the Cascade Mountains, about 11 km north of Yakima. The installation is large, encompassing 1064 $km^2$ of rugged shrub-grassland steppe between the Yakima and Columbia Valleys and occupying parts of Yakima and Kittitas Counties. The Yakima River, flowing south, runs just a few miles beyond the installation's western boundary; the Columbia River, also flowing south, forms much of the eastern boundary.

The landscape is characterized by northwest-southeast trending ridges, with ridgetop high points around 1200 m above sea level; the lowest elevations in the canyons run into the Columbia at around 150 m. In several valleys, the drainage runs both east into the Columbia (Cottonwood, Hanson, and Cold Creeks) and west into the Yakima (Squaw, Badger, and Selah Creeks). Dominant native plants are bluebunch wheatgrass and big sagebrush; cheat grass is an important invader. Sandburg grass dominates the rocky ridgetops, while giant wildrye frequents the valley bottoms. Because of limited moisture availability and frequent fires, the installation is treeless, except along some watercourses where there are occasional willows and cottonwoods. Wildlife at Yakima includes a population of Pronghorn Antelope which occupies the main impact area, as well as falcons, sage grouse, jack rabbits, and eagles.

The climax at the Yakima Firing Center is dramatically affected by the towering Cascade Range to the east. Most of the moisture of the Pacific air masses is lost in passing over the Cascades, and average annual precipitation at the firing center is only 224 mm (8.8 in.). July, August, and September are especially dry, and the danger of range fires is often high during this period. The wettest months are December and January, when much of the precipitation is snowfall. Summer temperatures are warm, but the nights are cool because of the dry air and generally clear skies. Winters vary, with spells of cold air descending from Canada, alternating with warmer Chinook air flowing down the eastern slopes of the Cascades. Winds are highest in March and April.[11]

Established in 1942, Yakima Firing Center is a subinstallation of Fort Lewis and has only a skeletal permanent troop assignment. However, the installation is used regularly by units of the 9th Division from Fort Lewis, by various National Guard and Reserve units, and by some Canadian troops. The wide-open, rugged country is especially suited for cross-country maneuvers, although road dust and range fires are problems during the long dry season. Much of the Firing Center's landscape has been crossed by tracked vehicles, but few areas have received intensive traffic. However, the dry steppe vegetation is easily destroyed or displaced by overruns of tracked vehicle traffic. If the 9th Infantry is converted to mechanized, it is estimated that tracked vehicle traffic at Yakima will increase 10 times.

## The Tracked Vehicle Training Ranges

Of these 12 installations, nine are under the U.S. Army Forces Command (FORSCOM) and three are under the U.S. Army Training and Doctrine Command (TRADOC) (see Table 2). Since FORSCOM's tracked vehicle training programs differ from those of TRADOC, to some degree the types of impact also vary. At Fort Bliss -- one of the three TRADOC installations -- the TRADOC activity is air defense training, but the tracked vehicle training is under FORSCOM; thus, the pattern of tracked vehicle training at Bliss is similar to that of FORSCOM installations. As a result, only Knox and Benning differ from the FORSCOM pattern.

The major function of the FORSCOM installation is to house and support troops. Maneuver lands are used for tasks that maintain troop proficiency.

[11] Fort Lewis, Washington, Terrain Analysis (ETL, 1978), p 43.

Table 2

The Installations -- Lands and Missions

| Installation | Command | Major Function | Date Opened | Total* Acreage | Availability Maneuvers Acreage | % of Total* Land for Maneuver |
|---|---|---|---|---|---|---|
| Benning | TRADOC w/FORSCOM | Infantry training | 1918 | 181,510 | 119,675 | 66 |
| Bliss | TRADOC w/FORSCOM | Air defense training | 1854 | 1,125,349 | 343,446 | 31 |
| Carson | FORSCOM | House-support troop | 1942 | 137,349 | 98,319 | 71 |
| Drum | FORSCOM | Reserve and guard center<br>Winter training | 1909 | 107,265 | 65,265 | 61 |
| Hood | FORSCOM | House-support troops | 1942 | 217,214 | 131,902 | 61 |
| Irwin | FORSCOM | Guard and reserve centers<br>Support large-scale training events | 1941 | 642,805 | 412,855 | 64 |
| Knox | TRADOC | Armor training center | 1918 | 110,392 | 57,400 | 52 |
| Lewis | FORSCOM | House-support troops | 1917 | 86,759 | 73,734 | 85 |
| Polk | FORSCOM | House-support troops | 1944 | 197,899 | 101,377 | 51 |
| Riley | FORSCOM | House-support troops | 1853 | 100,990 | 68,558 | 68 |
| Stewart | FORSCOM | House-support troops | 1940 | 284,923 | 252,567 | 89 |
| Yakima | FORSCOM | Support troops | 1942 | 263,131 | 227,301 | 86 |
| | | TOTALS | | 3,456,026 | 1,952,399 | 56 |

*Figures for total acreage and maneuver acreage were obtained from Training Land, TC 25-1 (Department of the Army, August 1978).

The degree to which these tasks include tracked vehicle training depends on the type of units (infantry, mechanized infantry, armored, engineer, etc.) and on the number of each type of unit assigned to an installation. The land-use pattern for tracked vehicle training depends on limiting topographic, biotic, and access factors; generally, however, all accessible areas receive some level of tracked vehicle training use. There are some favored areas of concentration, such as sparsely wooded slopes at Forts Hood and Carson; but, on these installations, the rolling grasslands and the alluvial valleys also receive extensive use.

The major function of TRADOC installations is to train troops in a specific set of skills. At Knox, troops are trained to use various armored vehicles, especially tanks. At Benning, the use of armored personnel carriers (APCs) is an important part of the training program. Making troops skillful with tracked vehicles involves a repeated use of certain areas. This intensive use rapidly degrades these areas and sometime makes them ineffective for further training. Essentially, the TRADOC pattern involves intensive use of limited areas, while the FORSCOM pattern involves varying use levels of extensive areas.

Table 3 gives a basis for comparing the relative levels of tracked vehicle cross-country traffic among installations. Note that these figures are only rough estimates, since they were calculated from very limited data.*

At some installations, the actual number of maneuver areas available for tracked vehicle use is much smaller than the total maneuver acreage. At Benning, for example, many maneuver areas are restricted to infantry usage; at Carson, several maneuver areas are closed for restoration. At Lewis, the dense Douglas fir stands limit tracked vehicle use in many maneuver areas; at Stewart, the high water table limits tracked vehicle traffic seasonally in some areas and all year in others. On these installations, the lands that remain available for tracked vehicle training receive more intensive use than is reflected in the column headed "Miles per year per acre" in Table 3.

This column suggests that the highest level of tracked vehicle traffic occurs on lands at Hood, Carson, Knox, and Riley. Visual observations of vehicle traffic impacts on soils and vegetation at these installations confirm these figures. Hood and Carson both have high levels of traffic over very extensive acreages, but the most intensive cross-country tracked vehicle use is at Fort Knox, along the Owl Creek watershed. On the rolling, clayey hills of this watershed, deeply eroding gulleys have resulted from years of concentrated traffic and rendered several areas untrafficable.

However, there are areas of high-level traffic on all the other installations. Even on the installations with the comparatively low miles per acre figures, such as Yakima, Irwin, and Benning, tracked vehicle training has noticeably changed the landscape in many areas.

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* The figures for number of vehicles were obtained from the G-3 on range control at each installation, and they were relatively accurate <u>at one time</u>. At some installations, such as Stewart, this number is rapidly changing. No figures were obtained for Drum, so it is not included in Table 3.

Table 3

Relative Tracked Vehicle
Usage Per Land Area

| Installations | No. of # Vehicles | Estimated Miles Cross Country Per Year | Annual Cross-Country Vehicle Miles | Available Maneuver Acres (From Table 2) | Miles Per Year Per Acre |
|---|---|---|---|---|---|
| Benning | 250 | 300 | 75,000 | 119,675* | 0.627 |
| Bliss | 750 | 500 | 375,000 | 343,446 | 1.092 |
| Carson | 950 | 400 | 380,000 | 98,319* | 3.865 |
| Drum | -- | -- | -- | -- | -- |
| Hood | 2500 | 400 | 1,000,000 | 131,902 | 7.581 |
| Irwin | 700+ | 500 | 350,000 | 412,855 | 0.848 |
| Knox | 1000 | 300 | 300,000 | 57,400 | 5.226 |
| Lewis | 375 | 200 | 75,000 | 73,734* | 1.017 |
| Polk | 750 | 400 | 300,000 | 101,377 | 2.959 |
| Riley | 750 | 400 | 300,000 | 68,558 | 4.376 |
| Stewart | 850 | 400 | 340,000 | 252,567* | 1.346 |
| Yakima | -(375) | 200 | 75,000 | 227,301 | 0.330 |

*Actual maneuver acreage available for tracked vehicle training on these posts is greatly reduced.

# 3 RESEARCH ACTIVITIES

The level of research CERL conducted at the 12 installations varied significantly. At Polk, Knox, Hood and Lewis, teams of reseachers spent several man-weeks making detailed studies of birds, mammals, and vegetation. Only limited observations of soils were made. Studies at the eight other installations were less detailed and were conducted to determine whether there were any noticeable differences between them and the four installations studied in detail. At Bliss, Irwin, Carson, Riley, Benning, and Stewart, one researcher spent 5 to 10 days at each installation studying the activities of small mammals and observing vegetation and soils. At Yakima and Drum, one researcher made limited observations of small mammal populations, vegetation, and soils during brief 2-day visits.

## Research Sites

### *Site Selection*

Sites were chosen for field studies at each installation. These sites would ideally represent areas of minimum and maximum tracked vehicle cross-country impact on the major habitat at each installation. However, several factors constrained these site choices:

First, attempts were made to select maximum- and minimum-use sites that were similar in terrain and vegetative features; however, it was generally difficult to locate comparable on-post minimum-use sites. Usually, whenever particular features (such as pinyon-juniper foothills on moderate slopes at Fort Carson) were favored for cross-country use, these features were used wherever they occurred on post. Similar, off-post sites were generally subject to different land uses, such as cropping and grazing. As a result, the minimum-use sites chosen generally had some small level of impact.

Second, distance was a significant factor in selecting sites, especially at Bliss, Yakima, and Irwin, where some maneuver areas were remote from cantonment and urban areas.

Third, access to certain areas, such as impact areas and firing fans, was restricted on every installation.

Fourth, rough roads and difficult terrain presented varying problems. At Irwin, Carson, Hood, Drum, and Yakima, many areas were difficult to reach due to rough roads, lack of roads, and rocky and steep terrain. Thus, the sites selected were generally near all weather roads and highways.

## Activities Conducted

Some or all of the following activities were conducted at the selected sites:

1. Small mammal species were taken, using snap traps baited with peanut butter and rolled oats. Traps were generally placed at 10-pace intervals

along line transects. Generally, trapping was done at a particular spot for only 1 to 2 nights.* Specimens captured were identified, measured, examined for species verification, and prepared for museum use. Table 4 summarizes the mammal trapping activities.

2. Plant samples were taken (cuttings from shrubs, trees, and vines; entire specimens from grasses and forbs). Specimens selected were either prominent at a particular site or indicative of successional and/or retrogression patterns resulting from military use. When possible, specimens were identified to the species level** at the site and then pressed.

3. To determine relative degree of impact, at least fifteen 100-m transects were walked at each site. At each pace, researchers determined whether that interval of land was impacted by observable vehicle tracks. Thus, percent impact would correspond to percent ground surface disturbed. (No transects were walked at Polk, Knox, Drum, or Yakima.)

One problem with this method is that tracked vehicle impressions vary significantly from one site to another, depending on soil type and condition. The sandy soils at Fort Bliss are subject to wind erosion, so vehicle tracks may disappear within a few days; however, on the clayey soils at Fort Riley, the evidence of a single vehicle passing, especially during wet conditions, may last for many years. Despite this problem, the transect method provides a simple tool for quantitative, though rough, comparisons of impacts among sites at an installation and among installations.

4. The compacting impact of tracked vehicle activity on research sites was measured with a pocket penetrometer. This device is pressed to a depth of 6.3 mm into the ground; the force needed to insert it is measured in tons of pressure per square foot. The device measures 1 to 5 tons per square foot of pressure in intervals of 0.25; for use in loose and unconsolidated soils, there is an adapter foot. This was used at Bliss and occasionally at Irwin and Carson; no readings were made at Drum, Polk, or Yakima.

5. Photographs were taken to record each site's characteristics and conditions.

## Additional Activities at Forts Polk, Knox, Hood, and Lewis

Extensive ecological surveys were conducted at Polk, Knox, Hood, and Lewis. The survey methods were designed to give detailed results.

* Some exceptions to these general procedures are noted in Table 4. At Polk and Knox, grids, rather than line transects, were used; at Knox, trapping was done with live traps.

**More detailed procedures were involved at Polk, Knox, Hood, and Lewis (see pp 28, 29 and 30).

Table 4

Mammal Trapping Summary

| Installations | Total Trap Nights | Method | Total Captures | % Capture Rate | No. of Species | No. of Nights | Period | No. of Sites |
|---|---|---|---|---|---|---|---|---|
| Benning | 332 | Line transects/snap traps | 35 | 10.5 | 3 | 4 | Nov, 1979 | 5 |
| Bliss | 363 | Line transects/snap traps | 29 | 8.0 | 4 | 2<br>2 | Oct, 1977<br>April, 1980 | 4 |
| Carson | 733 | Line transects/snap traps | 235 | 32.1 | 10 | 7 | April, 1980 | 8 |
| Drum | 258 | Line transects/snap traps | 18 | 7.0 | 4 | 2 | Oct, 1978 | 3 |
| Hood | 4944 | Line transects/snap traps | 121 | 2.4 | 7 | 18 | April/May, 1979 | 9 |
| Irwin | 496 | Line transects/snap traps | 157 | 31.7 | 8 | 5 | April, 1980 | 6 |
| Knox | 7185<br>1298 | Grids/live traps<br>line transects/snap traps | 100*<br>34 | 1.4<br>2.6 | 7<br>7 | 21<br>(12)** | April/May, 1979<br>April/May, 1979 | 3<br>6 |
| Lewis | 3840<br>6 | Line transects/snap traps/<br>underground mole traps | 145<br>2 | 3.8<br>33.3 | 6 | 12<br>(2) | June, 1979 | 4 |
| Polk | 4752 | Grids/snap traps | 13 | 0.3 | 5 | 12 | June, 1977 | 4 |
| Riley | 629 | Line transects/snap traps | 100 | 15.9 | 8 | 2<br>4 | Sept, 1977<br>April/May, 1980 | 5 |
| Stewart | 595 | Line transects/snap traps | 22 | 3.7 | 3 | 5 | Nov, 1979 | 5 |
| Yakima | 156 | Line transects/snap traps | 6 | 3.8 | 2 | 2 | Oct, 1978 | 3 |
| Totals | 25,587 | | 1017 | 4.0 | | 98 | | 65 |

*100 captures of 52 animals.
**Numbers in parentheses represent concurrent trapping activities and are not included in total.

*Fort Polk*

Mammals. Four grids measuring 100 by 100 m (1 hectare) each were surveyed. Traps were placed in clusters of three (one each of museum specials, standard mouse traps, and set traps) at 10- to 15-m intervals for a total of 198 traps per grid. The traps were baited late in the afternoon and run for 6 consecutive nights (1188 trap nights per grid). At first, the grids were run simultaneously. The traps were baited with a mixture of rolled oats and peanut butter. However, the tremendous number of ants in the grid areas consumed this bait in a few hours. Next, dry oats were tried, but the ants consumed them in about 1 hour. A final attempt used peanut butter alone, which lasted through the night in most cases.

All specimens taken were identified, tagged, and either prepared as standard study skins or placed in alcohol for preservation. These specimens were given to the University of Illinois Museum of Natural History.

Birds. Grids were permanently staked along their peripheries by 0.9-m wooden stakes at 30-m intervals. Similar stakes were positioned at various points inside the grid. Each stake's position was marked on a grid map and flagged with a white cloth to improve visibility. A map of each grid showed the location of each stake, along with other physical features. This allowed for precise plotting of each bird's position on the grid.

The researcher walked slowly north and south through the grid at intervals of about 30 m east to west, noting the following on the map: the position of each bird seen or heard, the bird's sex (if determinable), whether the bird was vocalizing, its behavior, and the direction and duration of flight if the bird left the grid.

When observations were done, all records of each species were plotted on a separate copy of the overall map. It was hoped that by studying the distribution of singing males, the number of breeding pairs of each species might be determined, using Kendeigh's "most points" method.[12]

Trees. All sites were 100 by 100 m (1 hectare). Grids were established on each site using tape measure and compass bearing. Flagging was set out along six rows at 20-m intervals, with six flaggings per row. The flag interval along the rows was 20 m.

Four quadrats labeled northwest, northeast, southwest, and southeast were established at each flag along each row. In each quadrat from each point, measurements were made to the closest tree that was 50.8 mm or larger in diameter at breast height (DBH) (four quadrats x six points x six rows = 144 measurements per grid). The distance from the point to the tree in feet and inches, the tree species, the DBH (in 0.1-in. intervals), and the last three complete years of growth (in millimeters) were recorded.

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[12] S. C. Kendeigh, "Measurement of Bird Population," Ecological Monographs, Vol 14 (1944), pp 67-106.

Mammals. Three 1-hectare grids were located in long-term, short-term, and control areas. Standard capture-recapture methods were used in which the animals were toe-clipped for marking purposes. Data were taken for 19 to 21 consecutive nights to estimate the populations using the Schnabel method.[13] The live traps were baited with a mixture of rolled oats, peanut butter, and cracked corn. Cotton was supplied for nest material and insulation. More data were obtained by trapping around the sinkholes near the control and long-term grids and in the brush piles on the control and short-term grids.

Birds. The grids used in the bird study varied in size. It was difficult to find areas of apparent equivalency (in terms of native vegetation) and still keep buffer zones between areas that differed naturally and/or in human-use pattern. All three grids were observed 15 times from 17 April to 11 May and from 29 June to 2 July 1978. Observation periods varied among early morning, late morning, or early afternoon for a total of 45 hours apiece. These periods were rotated daily to equalize the number of hours per interval spent on each grid.

Vegetation. All vascular vegetation was sampled in each of the three study sites. The percentage of the ground covered and the number of rooted stems of herbs and woody plants less than 2 m tall were counted from randomly placed 1/32-$m^2$ quadrats. DBH tallies were recorded by species for woody vegetation in 4- x 50-m quadrats established along randomly located transect lines. The transect lines and 50-m line intercepts were used to estimate woody vegetation cover that was more than 2 m tall. Increment cores were taken from random trees of all species in the 4- x 50-m quadrats except the diffuse porous species (sumac, dogwood, and maple). Prism samples were taken at 25-m intervals along transects to estimate basal area. Frequency was estimated by expressing the percent occurrence of each rooted species in the appropriate quadrat over the total number of samples taken at each site. Relative density (D), cover (C), and frequency (F) were calculated for each species sampled. These values were summed to derive an importance value (IV) for each species. Age, size relationships, and size-class frequency distribution for the more important trees were estimated from DBH and tree age data. The latter information was also useful for determining each site's vegetational history.

Vegetational communities maps showing the percentage of the ground covered by woody vegetation greater than 2 m in height and the percentage covered by vegetation less than 2 m in height were prepared for each site. Community designations were based on IV,[14] a method of quantifying dominance.[15] Community maps were prepared from 1:5000-scale aerial photographs, 1:24,000-scale U.S. Geological Survey topographic maps, the results of transect sampling, and additional field checking. Maps showing the percentage of ground cover were prepared from the species intercept data and the percent bare ground estimates made in the herb quadrats. The four cover classes used

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[13] R. L. Smith, Ecology and Field Biology (Harper and Row, 1974), p 718.

[14] John T. Curtis, The Vegetation of Wisconsin: An Ordination of Plant Communities (University of Wisconsin, Madison, 1959).

[15] Robert H. Whittaker, Communities and Ecosystems, 2nd ed. (Macmillan Publishing Co., 1975).

in mapping were: less than 25 percent, 25 to 50 percent, and 75 percent or greater. Peripheral communities that were not sampled were subjectively mapped relative to results from sampling other communities. Soils were examined in each community, and soil compaction was estimated to the 25-mm depth using a hand-held soil penetrometer.

All plants found from sampling and surveying were identified. The less common species were collected and deposited in herbaria at Warren Wilson College, Swannanoa, NC. All nomenclature follows Gleason and Cronquest.[16] Soil compaction was considered when establishing community delineations.

*Forts Hood and Lewis*

Mammals. Traps were set out across the control and test areas along line transects; individual traps were generally set at about a 10-pace (8- to 9-m) interval. Each trap line was baited for 2 consecutive nights; then the traps were removed and a new line was set out at another location in the control or test area. Specimens captured were examined and measured for species identification, and the skins and skulls were then prepared for museum use.

Results from the two sites were compared using a capture index -- the number of individuals of each species captured divided by the number of trap nights multiplied by 1000. A chi-square test was used to compare the populations of the three major species captured at the control and test sites. Biomass* was compared for each species and for species of the same guild type.

Birds. The survey method used combined the procedures of Emlen; Severinghaus; and Balph, Stoddart, and Balph.[17] Biomass information was obtained by combining the information presented in Norris and Johnson; Behle; Graber and Graber; Esten; Baldwin and Kendeigh; Poole; Amadon; and Oberholser.[18]

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* The number or weight of all organisms of a given designation in a specified habitat or region.

[16] Henry A. Gleason and Arthur Cronquest, Manual of Vascular Plants in the Northeastern United States and Adjacent Canada (D. Van Nostrand Co., Inc., 1963).

[17] J. T. Emlen, "Population Densities of Birds Derived from Transect Counts," Auk, Vol 88 (1971), pp 323-342; J. T. Emlen, "Estimating Breeding Bird Densities from Transect Counts," Auk, Vol 94 (1977), pp 455-468; W. D. Severinghaus, Guidelines for Terrestrial Ecosystem Survey, Technical Report N-89/ADA086526 (CERL, 1980); M. H. Balph, L. C. Stoddart, and D. F. Balph, "A Simple Technique for Analyzing Bird Transect Counts," Auk, Vol 94 (1977), pp 606-607.

[18] R. A. Norris and D. W. Johnson, "Weights and Weight Variations in Summer Birds from Georgia and South Carolina," Wilson Bulletin, Vol 70, No. 2 (1958), pp 114-129; W. N. Behle, "Weights of Some Western Species of Horned Larks," Auk, Vol 60 (1943), pp 216-221; R. R. Graber and J. W. Graber, "Weight Characteristics of Birds Killed in Nocturnal Migration," Wilson Bulletin, Vol 74, No. 1 (1962), pp 74-88; S. R. Esten, "Bird Weights of 52 Species of Birds (Taken from Notes of William Van Goider)," Auk, Vol 48 (1931), pp 572-574; S. R. Baldwin and S. C. Kendeigh, "Variation in the Weight of Birds," Auk, Vol 55 (1938), pp 461-467; E. L. Poole, "Weights and Wing Areas in North American Birds," Auk, Vol 55 (1938), pp 513-518; D. Amadon, "Bird Weights and Egg Weights," Auk, Vol 60 (1943), pp 221-234; H. C. Oberholser, The Bird Life of Texas, 2 Vols (University of Texas Press, 1974).

Vegetation. Vascular plants were divided into three groups for phytosociological sampling: (1) trees -- plants with woody stems greater than or equal to 50 mm in diameter at a height of 1.5 m; (2) small woody vegetation -- plants with woody stems less than 50 mm in diameter at a height of 1.5 m (this category includes saplings, tree seedlings, shrubs, woody vines, and cacti); and (3) herbaceous plants -- vascular plants without perennial above-ground parts.

Trees were sampled for density, frequency, and basal area, using an augmented variable-radius method.[19] At 30 stratified, random points in each stand, basal area for each tree species was estimated with a 10-BAF prism.[20] For density and frequency estimates, all trees were counted by species in an 18.3-m-diameter circular quadrat. To obtain size-class distribution data, diameters were measured on all trees within an 18.3-m-diameter circle at an additional eight randomly selected points in each stand. One hectare in each stand was sampled for trees. Increment cores were taken from several trees of the two dominant species to correlate age with diameter.[21] Total tree canopy cover was estimated in each of the circular quadrats.

At the centers of 30-tree quadrats in each stand, small woody vegetation was sampled in 6.1-m-diameter circular quadrats. Plants were counted by species for density and frequency calculations, and percent cover was estimated for each species.

Herbaceous plants were sampled in 0.5-$m^2$ quadrats at the centers of 30-tree quadrats in each stand. Plants were counted by species for density and frequency calculations, and percent cover was estimated for each species.

Absolute and relative values for frequency, density, and dominance were calculated for each species in the three categories of vegetation.[22] Importance percentages were calculated for each species by taking the mean of relative frequency, relative density, and relative dominance. A t-test was used to evaluate differences. Shannon-Wiener diversity was calculated for each vegetation category in each stand.

Linear regression equations were derived from tree-ring data and used to convert the measured diameters to age classes. These age-class distributions were tested to determine which distribution model best described the two woodlands.

Soils. Soil compaction was measured at 60 points in each stand (two points 0.5 m from each 30-tree quadrat center), using a Soil-test model CL-700 penetrometer. Transects were walked through the study sites to measure soil surface disturbance; a soil surface disturbance index (SSDI) was obtained by

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[19] E. L. Rice and W. T. Penfound, "An Evaluation of the Variable-Radius and Paired-Tree Methods in the Blackjack-Post Oak Forest," Ecology, Vol 36 (1955), pp 315-320.

[20] D. Bruce, "A New Way to Look at Tree," Journal of Forestry, Vol 5 (1955), pp 163-167.

[21] M. A. Stokes and T. L. Smiley, An Introduction to Tree-Ring Dating (University of Chicago Press, 1968).

[22] Bruce, pp 163-167; G. W. Cox, Laboratory Manual of General Ecology (W. C. Brown Co., 1967).

dividing the number of steps with any sign of man-made disturbance by the total number of steps.

## Publication and File Reports

The data in this report summarize much more extensive research. The information is from two sources: (1) published documents and technical articles, and (2) unpublished file reports. For further information, see the bibliography in Appendix A.

# 4 RESULTS OF SMALL MAMMALS DATA COLLECTION

## Fort Benning

The fauna of Fort Benning appear in successional stages. Grainivorous rodents such as *Peromyscus polionotus* usually dominate the early succession stages of vegetation which characterize areas impacted by tracked vehicles at Fort Benning. Wharton[23] states that "if the ground stays bare long enough, the beach mouse (*Peromyscus polionotus*) may take up residence (if breeding stocks are nearby)...In the grass stage, the cotton rat (*Sigmodon hispidus*) moves in, but disappears in the shrub stage as grass cover thins out." On the five small mammal trapping sites at Fort Benning, only two species were captured: the beach mouse (also called the old field mouse) and the cotton rat. Cotton rats were captured at only one site -- a field dominated by broom sedge and disturbed only by infantry foot traffic. Old field mice were captured at all five sites. Their populations tended to be higher on sites with greater tracked vehicle impacts, reflecting the vegetative retrogression caused by this type of disturbance.

Trapping data indicate that training impacts which cause vegetative retrogression enhance these areas for old field mice; however, the data are inconclusive about the types of small mammal species, if any, that might be displaced by training impacts.

## Fort Bliss

Small mammal trapping was conducted at Fort Bliss on two nights in October 1977 and on two nights in April 1980. Altogether, there were 363 trap nights* and 29 captures of five species at four different sites.

The spotted ground squirrel, *Spermophilus spilosoma*, is common in Trans-Pecos, Texas, although only one specimen was captured at Fort Bliss. According to Schmidly, "it is commonly found in association with mesquite, buckthorn, creosote-bush and sandsage brush...(and) in El Paso and Culberson Counties...it shows a decided preference for sandy areas."[24] While the single specimen was found on a low-impact site, it cannot be concluded from one specimen that this squirrel is negatively impacted by military activity.

One hispid pocket mouse, *Perognathus hispidus*, was found on an impacted area. This large *Perognathus* occurs rarely in the Trans-Pecos; however, when it does occur, it is associated with several habitats.

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* One trap set per night; e.g., one trap set for 2 nights gives 2 trap nights.

[23]Charles H. Wharton, *The Natural Environments of Georgia* (Georgia Department of Natural Resources, 1978), p 178.

[24]David J. Schmidly, *The Mammals of Trans-Pecos, Texas, Including Big Bend National Park and Guadulupe National Park* (Texas A&M University Press, College Station, TX, 1977), pp 70, 225.

The Ord kangaroo rat, Dipodomys ordii, was the only species captured at all four sites, accounting for 75 percent of the captures. Schmidly[25] indicates that this species "reaches its maximum abundance in El Paso County, where it is the most common rodent in the mesquite-covered sand dunes east of El Paso." Both Merriam (D. merriami) and Ord kangaroo rats occur at Fort Bliss; D. ordii favors sandy soils, and D. merriami favors areas of gravelly, desert pavement. Seeds make up 90 percent of the Ord kangaroo rat's diet.

Findley[26] reports that Peromyscus leucopus "is commonly found in sandy places...in sandy basins, such as the Tularoosa Basin, P. leucopus may be found living in sand accumulated around the bases of mesquites and other leguminous shrubs." One specimen was trapped at a site which had received 25 percent visible impact.

The northern grasshopper mouse, Onychomys leucogaster, which occurs commonly in association with Dipodomys ordii on sandy grasslands and mesquite stands, was captured at two sites. This mouse, which feeds mostly on insects, accounted for 84 percent of the specimens captured on these two sites.

There was no noticeable difference in the species captured, the number of captures, or total biomass (actual or adjusted) between impacted and unimpacted (or lesser-impacted) sites. However, it was difficult to determine levels of impact from the visual evidence of tracks on the blowing sands of the Tularoosa Basin. Furthermore, the data obtained was insufficient to derive conclusions.

In addition to impacts caused directly by tracked vehicle traffic, two other impacts disrupt the resident populations. Noise from maneuvers may cause stress to certain groups of animals, although the degree of stress is not known. Low-flying helicopters and aircraft can cause stress to big game animals, especially antelope. Health impairment or abortion could result if the noise is repetitive.

Fires caused by missile and artillery impact may destroy vegetation, small mammals, birds, and their habitat. However, they also benefit certain grasses by retarding shrub invasion, although grama grasses (Boutelona) may be adversely affected.

## Fort Carson

Small mammal trapping was done at Fort Carson on 7 nights at eight different sites during April 1980. In all, there were 733 trap nights and 234 captures of 10 different species.

According to Armstrong,[27] "the thirteen-lined ground squirrels favor areas of short-grass on sandy soils typically on a slight slope with a southern to eastern exposure." One ground squirrel, Spermophilus tridecemlineatus,

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[25] Schmidly, 1977, p 91.

[26] James S. Findley, Arthur H. Harris, Don E. Wilson, and Clyde Jones, Mammals of New Mexico (University of New Mexico Press), p 211.

[27] David M. Armstrong, "Distribution of Mammals in Colorado," Monogr. Mus. Nat. Hist., No. 3 (University of Kansas, 1972).

was trapped at Fort Carson; it was taken on disturbed (almost barren) grassland, with sandy soil and a slight slope exposed to the south.

The silky pocket mouse, Perognathus flavus, was taken at two sites. This mouse is widespread on semi-arid grasslands of the central and southern Great Plains, burrowing beneath yucca, opuntia, and low shrubs.[28] At one site, it was found in medium grasses in an unimpacted area; at the other, it was taken at the foot of a sandy slope in an area denuded by military traffic.

The Ord kangaroo rat was captured at six of the eight Carson sites. Armstrong[29] indicates that D. ordii occurs in arid to semi-arid areas up to about 8300 ft in Colorado and favors sandy soils; the subspecies D. o. richardsoni generally occurs in the drainage of the Arkansas River. At Fort Carson, this species was found in dry, sandy areas with sparse grasses and forbs. It had extensive burrow systems, which exposed patches of topsoil and appeared to enhance erosion.

At most sites, the Ord kangaroo rat accounted for only a small percentage of the total capture. Some were captured at a highly impacted site and others at a fairly unimpacted area. At one site, kangaroo rats were found in the midst of a prairie dog town in a highly impacted area. Altogether, only 18 D. ordii were captured at Fort Carson, accounting for only 8 percent of the total capture. From this limited observation, it appears that this species is generally tolerant of military tracked vehicle activity.

The western harvest mouse, Reithrodontomys megalotis, which generally nests aboveground, prefers open, grassy areas.[30] This species, which was encountered at four of the eight sites, occurred most often in the creek valley. It was encountered in grassy areas, in weed patches, and beneath shrub thickets. Although it occurred in areas of moderate disturbance, it was not found in areas of intensive use.

Deer mice, Peromyscus maniculatus, occurred at all eight Fort Carson sites, accounting for 157 of the 234 animals captured. P. maniculatus occurs throughout much of North America, and, according to Armstrong[31] "is the most abundant of Coloradan mammals." At Fort Carson, they were found in almost every possible habitat: in undisturbed grasslands, highly disturbed grasslands, and along creekbeds, in wooded areas, and in brush thickets. Of the six species captured in one unimpacted grassland/brushland site, only two were taken at a largely denuded site directly across the road: one kangaroo rat, and 27 deer mice. At the highly impacted site, both the absolute number and proportion of deer mice increased.

Deer mice, which eat grass, grains, insects, and invertebrates, adapt to numerous circumstances. Warren[32] reports, "They are found in the woods, among rocks, and in gulches and arroyos on the prairies...In newly settled districts they find their way into houses, and make themselves at home, just as the

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[28]Armstrong, 1972.

[29]Armstrong, 1972.

[30]Edward R. Warren, The Mammals of Colorado (University of Oklahoma Press, Norman, OK, 1942), p 195.

[31]Armstrong, 1972, p 195.

[32]Warren, 1942, p 200.

common house mouse does...They live in holes among the rocks and in and under logs, and in the ground; in fact they make themselves at home anywhere." From the results of this limited trapping activity at Fort Carson, it appears that deer mice can make themselves "at home" in areas of intense military disturbance, while other small mammal species are less adaptable.

The white-footed mouse Peromyscus leucopus, also occurs widely in North America, but at Carson was found less frequently than deer mice. Seventeen white-footed mice were captured, all at one site. Warren reports finding them "about brush heaps in the Arkansas River bottom,"[33] while Armstrong states that they "are abundant in riparian woodlands and brush communities in southeastern Colorado."[34] At Fort Carson, these mice were found in dense, deciduous vegetation along a watercourse. This area was impacted by tracked vehicle traffic, but was still characterized by thickets of brush and stands of trees.

The brush mouse, Peromyscus boylii, was encountered on three sites, but always in small numbers. It was found under a large cottonwood tree, on densely wooded slopes, and in a thicket near a creekbed. Two of these sites were undisturbed, as was the immediate vicinity of the third site where it was encountered. According to Armstrong, the brush mouse is typically found in pinyon and juniper woodland, at a maximum elevation of 8300 ft, with the northernmost record from south of Colorado Springs along Fountain Creek.[35] At Fort Carson, the brush mouse was apparently at the northern extent of its range.

The pinon mouse, Peromyscus truei, is a climbing mouse, nesting in trees and among rocks.[36] It is generally restricted to pinyon-juniper woodlands: various species of Juniperus provide its preferred nesting sites and winter food.[37] At Fort Carson, it was always encountered in association with pinyons and junipers. Although two sites were impacted by tracked vehicle activities, only one P. truei was found at a highly impacted site.

The Mexican woodrat, Neotoma mexicanus, also favors pinyon-juniper woodlands at elevations of 4300 and 8300 ft (1290 and 2490 m). The subspecies fallax is found in the foothills of the Colorado front range.[38] Captures of these woodrats occurred only on unimpacted rocky slopes. Some of the impacted sites appeared to provide suitable habitat for this species; however, the intensive military activity at these sites and in the surrounding foothills may have discouraged their presence.

Only one prairie vole, Microtus ochrogaster, was captured in an area of grasses and shrubs at the bottom of a secondary creek bed. Armstrong

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[33]Warren, 1942, p 204.
[34]Armstrong, 1972, p 205.
[35]Armstrong, 1972 p 208.
[36]W. H. Burt and R. P. Grossenheider, A Field Guide to the Mammals (Houghton Mifflin Co., 1976), p 163.
[37]Armstrong, 1972, p 209.
[38]Armstrong, 1972, p 223.

indicates that its "distribution is dendritic along streams, with the foothills of the Front Range at its western limit."[39]

While no species of the black-tailed prairie dog, Cynomys ludovicianus, were captured at Fort Carson, a survey between August 1975 and March 1977 found 40 prairie dog colonies, or towns, occupying an area of about 5000 acres, or about 3.5 percent of the installation lands.[40] This plump, pale-colored mammal is generally considered a pest on grazing lands, competing with livestock for forage. In the past, there have been major efforts to destroy prairie dog towns on Colorado rangeland. Koford reported, "The campaign against black-tailed prairie dogs was so effective that they are no longer considered a major agricultural problem."[41] However, populations of these mammals at Fort Carson are still high; recently, there have been reports of increasing populations in Colorado and other states.

Prairie dogs prefer hard-packed ground (so that their extensive burrows will not collapse) and short grasses. Herds of bison which overgrazed native grassland areas originally provided ideal habitat for these animals.[42] Later, "the great Chisholm Texas cattle trail through the Indian Territory, a hundred yards wide, became a Dogtown almost its entire distance," as a result of overgrazing and soil packing.[43] At Fort Carson, cross-country vehicle traffic on grasslands provides similar areas of hard-packed soil and short, sparse grasses. Burrow sites were common in a heavily traveled corridor along Route 1 and decreased with distance from this impacted area. While a similar relationship was noticed at the sites of other prairie dog towns, especially those along Route 1, there were also towns at sites with little or no military traffic.

The results of small mammal trapping at the eight Fort Carson sites indicate the tolerance of several species for military vehicle disturbance. Deer mice and Ord kangaroo rats appear to be most tolerant, with deer mice apparently increasing in disturbed areas. Prairie dogs also increase in impacted areas. On the other hand, it appears that western harvest mice, brush mice, pinon mice, and Mexican woodrats are all sensitive to military disturbances, although with varying degrees of tolerance.

There is no strong correlation between level of impact and rate of capture, or between level of impact and biomass (actual or adjusted), among the eight Fort Carson sites. At the most clearly comparable sites (1 and 2), the figures for rates of capture, adjusted number of captures, actual biomass, and adjusted biomass at the impacted site all exceed comparable figures for the unimpacted site. This is due to an increase in deer mice at this site. Yet despite the biomass increase at the impacted site, the species diversity was greater on the unimpacted site.

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[39]Armstrong, 1972, p 243.

[40]Anthony B. Rekas, Environmental Baseline Descriptions for Use in the Management of Fort Carson Natural Resources, Report 1, Development and Use of Wildlife and Wildlife Habitat Data, TR M-77-4 (Waterways Experiment Station, 1977, p 34-39.

[41]Rekas, 1977, p D14.

[42]E. Lendell Cockrum, Mammals of Kansas (University of Kansas Publ., Mus. Nat. Hist.), Vol 7, No. 11 (1952), p 24.

[43]Cockrum, 1952, p 24.

## Fort Drum

Small mammal trapping was done at Fort Drum in October 1978; there were 18 captures of four species at three different sites. In all, there were 258 trap nights.

While trapping activities were very limited, the pattern noted at other installations also occurred here. The four species captured at Drum were *Peromyscus maniculatus* (the deer mouse), *Microtus pennsylvanicus* (the meadow vole), *Clethrionanys gapperi* (the boreal redback vole), and *Blarina brevicauda* (the short-tail shrew). Populations of mice, voles, and shrews were found at unimpacted or slightly impacted sites of mixed trees (maple and oak) and shrubs. However, at highly impacted sites (also maple and oak woodland, but with less groundcover), only deer mice were captured, and in higher populations than at other sites.

Of the 12 installations, Fort Knox is the most similar to Fort Drum in terms of climate, vegetation, and wildlife. At Knox, as well as at Drum, shrews and voles showed a very limited tolerance for tracked vehicle disturbance; up to a certain level of disturbance, the numbers of mice (*Peromyscus*) actually increased.

## Fort Hood

Line traps were placed on nine sites over 18 nights, with 121 captures from 4944 trap nights. Most trapping was done on two sites: a test site on the west side of the post (2038 trap nights) and a control site on the east side south of Belton Reservoir (1864 trap nights).

More animals were captured at the test site than at the control site; also, the animals captured at the test site had greater biomass. However, only populations of the silky pocket mouse differed significantly (at the .05 probability level). This species, which is quite small (7 to 9 grams), comprised less than 30 percent of the total biomass from the test site. Although the mammal captures from the test and control sites generally did not differ significantly, it appears that the small mammal species found in the juniper-oak woodlands can tolerate the impacts of vehicle training activities, despite great changes of habitat and significant loss of vegetative cover. The adaptability of these species relates both to their habits and to the pattern of military land use.

At Fort Hood, the land-use pattern on impacted woodland sites results in wide corridors which receive frequent traffic and vegetated "islands" through which vehicles seldom pass. Sixty to seventy percent of the ground surface on the test site was frequently disturbed; however, the undisturbed islands on the remaining 30 to 40 percent were of adequate size and proximity to one another to provide refuge for a small mammal population. This population was equal to or greater than that of the undisturbed areas. This pattern of training land use in the oak-juniper woodlands occurred widely at Fort Hood and had been established over many years of intensive off-road traffic. Eighteen months after this study, the test site was in about the same condition. There was only minor evidence of increased damage to the vegetated islands; however, all the small mammals except the silky pocket mouse

(Perognathus flavus) were found in these areas. Further loss of vegetation and habitat disruption could reduce the mammal populations. Yet these remaining islands of vegetation are necessary to provide cover for maneuvering vehicles; thus, it is not likely that they will be further degraded.

From previous studies[44] at Fort Knox, it was predicted that extensive tracked vehicle activity would have a "positive and moderate" effect on the den-nest-cover parameter. Impacts would have a "negative but minimal" effect on the food parameter for the mammal/seed eater/secretive nest-dwelling guild in which species of the genus Peromyscus are categorized. Both the pattern of impact and the terrestrial environment at Fort Knox differed significantly from those of Fort Hood. Yet at Knox, as at Hood, there was an overall increase in populations of Peromyscus. (At Knox, these mammals were from the species Peromyscus leucopus.) King[45] writes that "It is likely that such species as P. boylei, P. californicus, P. leucopus, P. maniculatus, P. melanophrys, and P. pectoralis have been considerably favored by man's operations. Since the coming of European man, land-use practices (grazing by domestic livestock, lumbering, suppression of fires, clearing, and cultivation) have increased the amount of brushlands."[46] Off-road tracked vehicle training activities disturb both mature woodlands and grasslands. This produces various mixed "brushlands" where annual forbs are a predominant herb cover, as well as persisting or invading trees/brush. These disturbed environments are apparently suitable for several species of the genus Peromyscus; the annual forbs produce abundant seed crops, supplementing (or supplemented by) tree and brush mast; the trees/brush provide den-nest-cover needs. And, "Except for grassland areas, swamps, and deserts, where other rodents may be dominant, species of Peromyscus usually are the most common mammals present."[47]

In the undisturbed oak-juniper woodlands at Fort Hood, there were natural canopy openings and many understory trees. The herbaceous stratum was dominated by perennial grasses and sedges. On the test site, there was a significant decrease in the aerial coverage of trees, woody understory, and herbaceous plants. However, the overall number of herbaceous plants increased significantly, as grasses and sedges shifted to weedy annuals. This shift increased seed production, which may be a factor in the impacted woodlands' ability to sustain small mammal populations.

The two Peromyscus species attwateri and pectoralis, were found on both test and control sites. There was no evidence that training activities affected these mammals adversely. They are tolerant of human disturbances, and the pattern of vehicle activities resulting in undisturbed refuges allowed their populations to be maintained. Food resources continue to be available. These factors minimize any adverse impacts.

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[44] W. D. Severinghaus, R. E. Riggins, and W. D. Goran, Effects of Tracked Vehicle Activity on Terrestrial Mammals, Birds, and Vegetation at Fort Knox, KY, Special Report N-77/ADA073782 (CERL, 1979), p 64.

[45] John A. King, ed., "Biology of Peromyscus," Spec. Publ. No. 2, Amer. Soc. Mammal (1968), p 114.

[46] King, 1968, p 114.

[47] King, 1968, p 114.

Fort Irwin

Small mammals were trapped on 5 nights at six sites for a total of 496 trap nights and 157 captures of eight species. The white-tailed antelope squirrel, Ammospermophilus leucurus, occurred on three of the six sites. These ground squirrels prefer rocky areas, but occur throughout areas of creosote bush shrub. They are active during the day throughout the year, feeding on seeds, new vegetation, and insects, and burrowing nearly vertical tunnels beneath rocks and at the base of shrubs. A. leucurus were captured both on flats and on rocky slopes; however, none were found near previous vehicle activity, which may reflect their sensitivity to maneuver impacts.

The little pocket mice (Perognathus longimemobris) were caught at every site, accounting for 80 of the 157 animals captured. Populations were high at all sites, but especially on the desert flats. This mouse prefers open areas and sandy soils or fine gravelly soils.

The long-tailed pocket mouse (P. formosus) prefers gravelly and rocky habitats; it occurs frequently in or near hot desert canyons.[48] It was captured only on the slopes of the Paradise Mountains. Its presence or absence apparently relates to natural circumstances, rather than military land use.

One desert kangaroo rat (Dipodomys deserti) was captured on the fine sands of a lower slope; many other burrows were evident in the area. It occurs at low elevations, often in colonies. No capture occurred in impacted areas; however, no impacted areas that were surveyed provided similar habitat.

The Merriam kangaroo rat was found on five sites. This species is common on creosote bush scrub in the Mohave Desert, digging its burrows under creosote bushes.[49] Unable to climb, it does not inhabit rocky slopes; thus, it was not found on sloping, gravelly wash sites.

The deer mouse, which is very abundant at Carson, was found on only one site at Irwin. It occurs at various elevations and habitats throughout the desert, sometimes in populations of 10 or 15 to an acre;[50] it appeared more frequently in previous trapping at Irwin.[51]

The southern grasshopper mouse, Onychomys torridus, occurred on all six sites; however, this species did not comprise a large percent of the total capture at any site. The grasshopper mouse, which feeds on 90 percent animal matter and often nests in burrows of other animals, occurs in open and scrub desert areas throughout the lower Sonoran zone in Southern California. No relationships between military impact and grasshopper mice populations were apparent from trapping results.

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[48]Ingles, Lloyd Glenn, Mammals of California and Its Coastal Waters (Stanford University Press, 1947), p 221.

[49]R. Mark Ryan, Mammals of Deep Canyon, Colorado Desert, California (The Desert Museum, Palm Springs, CA, 1968), p 92.

[50]Edmund C. Jaeger, Desert Wildlife (Stanford University Press, 1961), p 76.

[51]Environmental Impact Assessment for Fort Irwin, CA (Headquarters, Reserve Components Training Center, California National Guard, Fort Irwin, CA, January 1978).

The desert wood rat (Neotoma lepida) was found nesting on large rock outcrops of the Paradise Mountain slopes. While the desert wood rat is not limited to rocky sites, none were encountered elsewhere. No relationship can be drawn between military activity and their presence or absence.

Military use varied significantly among sites, and there was an obvious decrease in vegetative biomass on impacted sites. The capture rate at each site was similar, even though degree of impact differed. Also, both the number of species captured and the total biomass were very similar for all sites, when adjusted for variable trap nights. Thus, current levels of training maneuvers do not appear to greatly affect the small mammal populations at Irwin.

Vollmer, who studied sites impacted by off-road vehicles on the northern Mohave Desert in Nevada, also found that damage to shrubs and herbs did not necessarily reduce small mammal populations. "The exposure of portions of our study area -- over a period of 6 months -- to a total of 4 or 5 hours of driving by trucks affected both annual and perennial vegetation...changes in apparent densities of vertebrates were not clearly interpretable...The available evidence shows no indication that driving interfered with reproduction by rodents in the test area. Rather, the possibility should be considered that the greater number of young rodents in the test area was in some way associated with the use of vehicles."[52] Vollmer then suggested that increased sprouting from damaged shrubs may have caused the rodent increase he observed, since there is an association between herb production and rodent reproduction.[53] He also emphasized that increased sprouting as a result of damage is a short-term response to cross-country traffic impact, and that the small mammal increase "pertained almost entirely to heteromyid rodents."[54]

Other researchers stress the susceptibility of desert fauna to vehicle damage. Bury, Luckenbach, and Busack state, "It is important to realize that the creosote shrub community is an ancient, diverse assemblage of plants and animals. The shrubs themselves may require decades to mature, and even partial damage to the plants, particularly the root systems, may subject them to stress in dry years or droughts. ORVs cause loss of topsoil and compaction. Traffic around shrubs decreases food for birds and small mammals by dispersing and burying seeds and disrupting the soil mantle."[55] It is further stated, "We have estimated that a square kilometer of comparable creosote shrub habitat would contain about 6650 terrestrial vertebrates weighing about 285 kg. According to our study, heavy ORV use over 1 $km^2$ would destroy about 3000 individuals and 220 kg of animals. In moderate-use areas, there would be a decline of 830 individuals and 185 $kg/km^2$."[56]

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[52] A. T. Vollmer, B. G. Maza, P. A. Medica, F. B. Turner, and S. A. Bamberg, "The Impact of Off-Road Vehicle on a Desert Ecosystem," Environmental Management, Vol 1, No. 2 (1976), pp 123-124.
[53] Vollmer, 1976, p 127.
[54] Vollmer, 1976, p 127.
[55] R. B. Bury, R. A. Luckenback, S. D. Busack, Effects of Off-Road Vehicles on the Vertebrate in the California Desert, Wildlife Report 8 (U.S. Fish and Wildlife Service, 1977), p 16.
[56] Bury, Luckenback, and Busack, p 16.

From the limited trapping data completed at Irwin, the results resembled those of Vollmer, with "changes in apparent densities of vertebrate not clearly interpretable."

## Fort Knox

A study of small mammals populations[57] at Fort Knox indicated that there is generally a modest impact on small mammals when areas are prepared for tracked vehicle training, and a severe impact when these areas are used extensively and over a long period of time.

The short-term area had 18 to 20 percent less biomass than the control area, and the long-term area had 65 to 68 percent less biomass than the control area. It appears that clearing hardwood forests to simulate a western European scenario will immediately reduce an area's capacity to sustain small mammal life by about 20 percent. Also, extensive and long-term use of such areas can produce a biomass loss of almost 65 percent. Although this information does not consider the desirability of the various species, it can estimate the area's abilities to sustain small mammal populations.

There was ample evidence that mammals which spend their entire lives either on or below (but near) the surface are more severely impacted by such training activities than those which climb in brush and trees sometime during their lives. The major cause-effect relationships appear to be disturbance of the soil surface by the compacting and scraping activities of clearing, and the soil compaction, vegetative disturbance, and resulting erosion caused by training. The primary niche parameter affected is the removal of or damage to the nesting and cover needed for survival after loss of food resources (initially, vegetative growth and secondarily, seed production).

The effects of clearing forested land for training activities as practiced at Fort Knox are very disruptive to some small mammals. About 90 percent of the short-tailed shrew (*Blarina brevicauda*) population is lost when the sites are prepared for training. The rest is lost as training progresses. Loss of vegetative cover, resulting erosion, and soil compaction are probably the biggest factors affecting this species. The pine vole (*Microtus pinetorum*) showed an 88 percent loss of population during clearing operations at short-term sites and a 100 percent loss at the long-term site. Data on the prairie vole are minimal: only three were taken on the test grids. However, since no ground cover was left after the area had been cleared, this species could not be expected in the short-term area. The house mouse (*Mus musculus*) was observed only in the short-term area. The absence of this species in the long-term area is probably due to lack of sufficient vegetation for cover and food.

Tracked vehicle training affects mammals more than the clearing process. The shrew, vole, and ground squirrel guilds all lost large amounts of biomass. Shrews and voles are exclusively surface dwellers, inhabiting nests or dens either on the surface or just below the surface. Ground squirrels are

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[57] W. D. Severinghaus, R. E. Riggins, and W. D. Goran, *Effects of Tracked Vehicle Activity on Terrestrial Mammals, Birds, and Vegetation at Fort Knox, KY*, Special Report N-77/ADA073782 (CERL, 1979).

somewhat similar, preferring to stay on the ground, although they will climb occasionally. All three guilds lost some food resources, with voles losing most of their resources. However, populations of white-footed mice showed a distinct increase, since their preference for climbing and for eating seeds (as compared to grass eaters) allowed them to replace the voles and ground squirrels.

## Fort Polk

Extensive small mammal trapping was done at Peason Ridge, Fort Polk, in June 1977, but only a few captures resulted. In all, there were 4752 trap nights from four grids, with 13 captures of five different species. Trapping was conducted in 120-m-square grids, with two test (impacted) sites and two control (less-impacted) sites.

Of the 12 installations studied, Fort Polk had the lowest population of small mammals. Thus, despite the significant number of trap nights, captures were insufficient for statistical analysis or for general conclusions. However, a few observations can be made from these limited results.

Of the five species captured, four (*Blarina brevicauda* - the shorttail shrew; *Cryptotis parva* - the least shrew; *Reithrodontomys humulis* - the eastern harvest mouse; and *Peromyscus leucopus*, the white-footed mouse) were captured only from the control grids. All of these small mammals are eastern species (although *Peromyscus leucopus* is found throughout much of North America), and all require mesic, or somewhat mesic, conditions. The fifth species (*Perognathus hispidus* - the Hispid pocket mouse) was captured only on the test grid. The Hispid pocket mouse normally occurs in dry, semi-arid, or arid conditions of short grass, friable soils, and sparse vegetation.[58]

In Louisiana, the Hispid pocket mouse is at the eastern extreme of its range. The presence of this mouse on the test grid may reflect the locally xeric, sparsely vegetated, and loose surface soil conditions that occur on impacted sites at Peason Ridge. The presence of the silky pocket mouse (*Perognathus flavus*) on the test site at Fort Hood may relate to a similar phenomenon. In areas of limited to moderate precipitation and/or high evapotranspiration rates, repetitive tracked vehicle traffic can create locally xeric conditions.

## Fort Riley

Small mammal trapping was done at Fort Riley at two sites on 2 nights in September 1977, and at four sites on 4 nights in April and May 1980. In total, there were 629 trap nights and 100 captures from eight different species.

Of the species captured, the short-tailed shrew (*Blarina brevicauda*), which prefers moist and wooded areas, was found only once beneath a thicket of shrubs and osage twigs. It was taken in the only area on any of the four

[58] W. H. Burt and R. P. Grosseuhelder, *A Field Guide to the Mammals* (Houghton Mifflin Co., 1952), p 142.

installations in which traps were left for a second night; this may indicate that these shrews prefer to become familiar with a strange object, such as a trap, before exploring it.

The western harvest mouse, also encountered at Fort Carson, was found at all five sites at Riley, although always in small numbers. In eastern Kansas, this species is found in tall grasses and brush thickets and along fence rows.[59] At Fort Riley, these mice were usually trapped in undisturbed grassy areas, although some also were found at weedy sites. At each of the three relatively undisturbed sites, harvest mice accounted for a higher percent of the total animals captured than at the two highly impacted sites. The western harvest mouse may be sensitive to military disturbance because it nests on the ground surface or in low vegetation.

The white-footed mouse was also found at all five sites and was the most abundant species captured at four of the five sites. Cockrum reports that in eastern Kansas, _Peromyscus leucopus_ inhabits woodlands.[60] While _P. leucopus_ was captured in woodlands, it was also found in grasslands, around farmsteads, in brush thickets, and in largely denuded areas. This species' response to impact was similar to the response of deer mice at Fort Carson -- it increased in dominance with increasing impact.

Though prominent at Fort Carson, and common throughout Kansas, the deer mouse was found only next to roads and near cultivated fields at Fort Riley.

The eastern wood rat, _Neotoma floridana_, was captured at two sites; at both sites it was nesting in osage trees. Other large nests were frequently sited in osage hedges. Anthony[61] states that "these rats (wood rats) build large conspicuous nests of dead twigs, leaves, and debris of various sorts, this habit being especially obvious in the deserts and arid plains...from the Great Plains westward, the genus (_Neotoma_) is represented by many forms, and nearly every peculiar environment has its own distinct race." Apparently, in eastern Kansas, the eastern wood rat has adapted to the specific environment created by osage orange trees, which were frequently planted as field hedges. These hedges are abundant in the parts of the installation that were previously farmed. "The eastern subspecies," reports Cockrum,[62] "_N. f. osagensis_, inhabits wooded areas and usually constructs a nest in a brush pile, under a fallen tree, around the base of a tree, or less frequently, in the branches of a tree. Its nests are often seen along fence rows of osage orange trees."

The occurrence of wood rats in osage trees was apparently unaffected by military activity, since nests were equally abundant in impacted and unimpacted areas. However, the osage thickets provided excellent protection. Only at one site, where the trees had thinned, was there evidence of a vehicle crossing a hedge.

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[59]E. Lendell Cockrum, _Mammals of Kansas_ (University of Kansas Publ., Mus. Nat. Hist.), Vol 7, No. 11 (1952), p 24.
[60]Cockrum, 1952, p 177.
[61]H. E. Anthony, _Field Book of North American Mammals_ (G. P. Putman's Son, 1928), p 392.
[62]Cockrum, 1952, p 189.

The prairie vole is a grassland species; it prefers moist sites and feeds on grasses, clover, alfalfa, and weedy forbs. In winter, it may favor habitats with some woody vegetation. It is active all year. At one time this species was abundant throughout Kansas, with populations as high as 2500 per square mile.[63] Prairie voles, also referred to as meadow mice, are a favorite food of many predatory birds. During the 1980 spring survey, many areas on and off post were being burned, and hawks would circle the skies above these areas in search of these rodents, which were no longer hidden by grass cover. One red-tailed hawk was seen capturing a vole from a road-ditch along Highway 18 near Manhatten Airport.

The prairie vole was encountered at all of the Fort Riley sites and accounted for one-third of the total captures at three sites. These voles were most prominent in the moist grasses along a road ditch, but they were frequently captured in thickets of buckbrush and rough-leaved dogwood. While some voles were encountered on the heavily impacted sites, they were usually found in locally undisturbed areas.

The results of mammal trapping activity do not indicate a decline in small mammal populations or small mammal biomass on the impacted sites. However, they do suggest that there was a shift in species composition, with decreases in prairie voles and western harvest mice and increases in white-footed mice in areas of intensive military activity.

In comparison with both previous and present surrounding cropping and ranching activities, the overall impact of the military use of Fort Riley lands may benefit most indigenous small mammal populations. Populations of small mammals were estimated to be as much as 50 times higher on Fort Riley than in surrounding farm and ranch lands.[64] Much higher populations of grassland species, such as harvest mice and voles, were found at Fort Riley than at the Konza Prairie Research Area, an 8100-acre tallgrass prairie tract only a few miles east of Fort Riley. It was suggested that small mammal populations were relatively high on Fort Riley because the military land use and management has resulted in diverse and inter-mixing areas of grasslands, shrublands, forblands, and woodlands in which many species can find suitable nesting sites and food sources.

Military training activities have degraded the native prairie vegetation at Fort Riley; however, the resulting increase in weedy forbs and woody species have generally benefited wildlife populations. White-tailed deer populations on post appeared to be among the most healthy in Kansas; populations of Eastern-fox squirrel, whitetail deer, Eastern cottontail, bobwhite, mourning dove, and prairie chicken are all higher on post than in the surrounding countryside.[65] However, populations of ring-necked pheasants appear to be lower on post. The Fort Riley Fish and Wildlife Office maintains an active program of wildlife enhancement, including food plots, controlled burning, and some stocking; this program accounts for much of the high wildlife population levels. Thus, the net effect of training activities and wildlife

[63] Cockrum, 1952, pp 201-202.
[64] Personal Communication between W. D. Goran (CERL) and Steve Fretwell (Kansas State University, Manhattan, KS), 1980.
[65] Personal communication between W. D. Goran (CERL) and Scott Clinger (Fort Riley Fish and Wildlife Office), 1980.

management is a mixed and varied environment that benefits many wildlife species.

## Fort Stewart

Four species were captured from trapping on five sites at Fort Stewart, including the old field mouse (*Peromyscus polionotus*), the cotton mouse (*Peromyscus gossypinus*), the house mouse (*Mus musculus*), and the least shrew (*Cryptotis parva*). Twenty-two animals were captured; of these, 18 were old field mice. The capture rate of old field mice at Fort Stewart was highest where the percent of ground impacted was high. Both populations of old field mice and the number of gopher tortoise (*Gopherus polyphemus*) burrows tended to increase in areas of tracked vehicle training.

## Yakima Firing Range

At Yakima, small mammal trapping was done at three sites on 2 nights in October 1978. In all, there were six captures from 156 trap nights.

No conclusions can be drawn from these limited trapping results. Only two species were captured: *Peromyscus maniculatus* (the deer mouse) and *Perognathus parvus* (the great basin pocket mouse). One *Perognathus* and one *Peromyscus* were captured in an area of mixed grasses on a moderately impacted hillside; the other four captures, all *Peromyscus*, were made along a stoney hillside just above a creekbed. This area was grazed, but not impacted by tracked vehicles. A few traps were placed at a highly impacted range firing table, but no captures were made at this site. Presumably, small mammal populations at Yakima are affected by both tracked vehicle activity and by grazing and rangefires. However, there is insufficient data to determine these effects.

# 5 RESULTS OF BIRDS DATA COLLECTION

## Fort Hood

Tracked vehicle training at Fort Hood has produced about a 40 percent loss of bird biomass in areas of maximum training. This is not unusual; results elsewhere are very similar.[66] Another important impact is the change in diversity. The number of species stayed relatively the same (28 at the test site and 31 at the control site); however, only 15 species were found in common between the test and control sites. Training caused a reduction or loss of the sensitive, pure woodland species and a gain in the edge, less-sensitive, and disturbed-site species.

If training continues at the present level, distribution and intensity of course changes should not occur. An increase in areas already used for training or the opening of new areas would cause a corresponding change in bird population structures. The major problem would be the continued loss of some of the more sensitive and habitat-restricted species. This could be critical to the continued existence of those species in the general area.

## Fort Knox

The overall impacts of short- and long-term training areas on bird populations were negative. There was a 20 percent reduction in biomass at the short-term area and a 60 percent reduction at the long-term area. The main parameters affecting birds were the understory disturbance, disruption of vegetative stratification, and soil surface disturbance.

Study results showed that the impacts of the methods used to prepare the land for tracked vehicle training cause a moderate (20 percent) reduction in bird populations. This information indicates a total reduction in biotic productivity; however, a detailed examination of each "resident" species is needed to understand the causes of this reduction. Data show that populations of woodland species are severely reduced (wood thrush, tufted titmouse, red-eyed vireo, and carolina chickadee). Populations of species that prefer an open woodland or forest edge habitats are moderately reduced (cardinal, common

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[66] W. D. Severinghaus, W. D. Goran, G. D. Schnell, and F. L. Johnson, Effects of Tactical Vehicle Activity on the Mammals, Birds, and Vegetation at Fort Hood, TX, Technical Report N-113/ADA109646 (CERL, 1981); W. D. Severinghaus, R. E. Riggins, and W. D. Goran, Effects of Tracked Vehicle Activity on Terrestrial Mammals, Birds, and Vegetation at Fort Knox, KY, Special Report N-77/ADA07382 (CERL, 1979). W. D. Severinghaus, and W. D. Goran, Effects of Tracked Vehicle Activity on Terrestrial Mammals, Birds, and Vegetation at Fort Lewis, WA, Technical Report N-116 (CERL, 1981); W. D. Severinghaus, R. E. Riggins, and W. D. Doran, "Effect of Tracked Vehicle Activity on Terrestrial Mammals and Birds at Fort Knox, Kentucky," Trans. Kent. Acad. Sci. (1980), 41 (1-2); pp 15-26; W. D. Severinghaus and M. C. Severinghaus, "Effects of Tracked Vehicle Activity on Bird Populations," Environmental Management, Vol 6, No. 2 (1982); Environmental Impact Assessment for Fort Irwin, CA (Headquarters, Reserve Components Training Center, California National Guard, Fort Irwin, CA, 1978).

flicker, common crow, catbird, and mourning dove). Species that prefer open, bushy habitats were impacted positively (rufous-sided towhee and red-winged blackbird). It also appears that insectivorous species, such as the vireos and warblers, are reduced much more severely than seed-eating species, such as the cardinal.

The almost 100 percent reduction of most "resident" species in the long-term area indicates the severely eroded and vegetatively denuded terrain. The species found most frequently in the long-term impact area were the red-tailed hawk, turkey vulture, and eastern kingbird. It is probably easier for these species to locate and/or capture prey, carrion, and insects, respectively, in the open area.

## Fort Lewis

Tracked vehicle training on Fort Lewis has resulted in about a 25 percent loss of bird biomass in areas of maximum training.[67] The second most important result is the change in diversity. The number of species stayed the same (six at the test site and eight at the control site), but only four species were found in common between the test and control sites. These were the barn swallow, American robin, western meadowlark, and savannah sparrow. The reduced numbers of robins, meadowlarks, and the common flicker may have been caused partly by the loss of food resources due to soil compaction by vehicles; all three of these species prefer to feed on the ground on a variety of large, nonflying invertebrates.

## Fort Polk

The bird population of an area which was heavily used by tanks was compared to that of an undisturbed area. It was found that some bird species seemed to prefer the undisturbed habitat; others seemed to benefit from effects of tank training because the altered habitat favored these species.

The reasons that a particular species preferred one grid over another were not always clear. However, these preferences could be correlated with habitat differences in some cases: pinewoods sparrows were more abundant on the control grid because of greater grass cover; prairie warblers and blue grosbeaks probably preferred the test grid because disruption by tanks allows the invasion of broad-leaved herbs and shrubs in an understory normally inhabited by various species of grasses and small trees; yellow-billed cuckoos may have preferred the test area because tanks created the "roadsides" and "clearings" beside which they usually nest. Some species such as the cardinal, blue-gray gnatcatcher, and Carolina chickadee apparently had no preference.

Tank training activities apparently do not adversely affect all species of birds; in fact, some species prefer the disturbed areas. The reasons for

[67] W. D. Severinghaus, R. E. Riggins, and W. D. Goran, "Effects of Tracked Vehicle Activity on Terrestrial Mammals and Birds at Fort Knox, Kentucky," Trans. Kent. Acad. Sci. (1980), 41 (1-2); pp 15-26.

these preferences merit further study, since they are due to complex interactions of factors such as food availability, presence of suitable nest sites, and availability of singing posts and cover.

## 6 RESULTS OF VEGETATION DATA COLLECTION

### Fort Benning

Generally, tracked vehicle training occurs on sandy ridges forested by longleaf pine and turkey oak; frequently used areas are either sparsely forested or open fields. In open areas, track vehicle disturbances to the plant and animal communities create a successional pattern similar to what Odum[68] describes as "old field succession." The most highly disturbed sites are barren. Revegetation of these sites first usually involves poor joe, (*Diodia teres*) and pineweed (*Hypericum gentianoides*), followed by horseweed (*Erigeron sp*) and broom sedge (*Andropogen virginicus*). If undisturbed, the broom sedge is eventually replaced by invading trees, such as sumac, persimmon, and sassafras, then scrub oaks, and finally pines. However, lands used continuously for tracked vehicle maneuvers remain in early successional stages.

### Fort Bliss

Much of the Tularoosa Basin is characterized by sand dunes topped with torrey mesquite. This shrub is vital in stabilizing the easily eroded soils of the desert basin. Generally, tracked vehicles travel between the dunes and avoid the dune slopes and mesquite shrubs. However, vehicles sometimes sideswipe the dunes, displacing the loose sands and exposing mesquite roots. Less frequently, vehicles drive directly over the dunes, crushing above-ground vegetation and damaging roots. Where such practices occur repeatedly, problems of dune drift, increased erosion and dust, and loss of mesic, shaded habitat have increased.

While direct damage to the dune shrub vegetation was only infrequently observed during field surveys, there were often areas where interdune vegetation suffered. On sites receiving intensive and repeated traffic, interdune vegetation was either very sparse or completely absent.

Another commonly observed impact of both maneuver activities and previous grazing was the invasion of undesirable weedy species. Russian thistle and broom snakeweed are prominent among these. Russian thistle is especially evident along the roads and tank trails, while broom snakeweed has become a dominant interdune species throughout the eight maneuver areas.

The relic grassland communities, which occur at scattered locations within the eight maneuver areas, have suffered major impacts. Arid grasslands appear less able than shrublands to sustain the impacts of vehicle traffic. Grasses are especially susceptible to damage in arid and semi-arid situations, because water stress has decreased their resilience. Due to military traffic, these grass communities, which occur on only limited acreage within Fort Bliss' maneuver areas, are quickly replaced by weeds or encroaching shrublands.

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[68]Eugene P. Odum, *Fundamentals of Ecology* (W. B. Saunders Company, 1971).

## Fort Carson

The semi-arid foothills and plains of Fort Carson are among the most intensively used Army lands. In Spring 1980, signs of tracked and wheeled vehicle training impacts were abundant. Vehicle tracks criss-crossed the plains, circled the pinyon and juniper trees on the wooded slopes, and ran into the bottomlands, frequently crossing dry streambeds. Numerous areas were denuded, grasses were often replaced by weedy forbs, and many woodland trees were damaged or destroyed because of vehicle traffic. Clouds of dust accompanied the movement of vehicles along the unimproved roads and trails, impairing the penetration of sunlight and nutrients.

Fort Carson's lands have not only received intensive use, but they have also shown a low tolerance to military disturbance. "By and large, adverse impacts are further aggravated by the relatively thin atmosphere, low precipitation levels, scarce water resources and thin soil covers, all of which produce much lower threshold bearing capacities (than) more humid and temperate locales...the available land is being abused at a rate that does not allow reasonable time for recovery."[69]

The semi-arid vegetation appears to have a lower tolerance to military disturbance than either the more xeric shrublands of installations in Texas and California or the more mesic grasslands and woodlands of installations to the east. This low tolerance results partly from Fort Carson's location at the geographic boundary of major biotic provinces. Many of the plains grasses occur at their highest altitude and westernmost extreme along the Rocky Mountain Front Range. Likewise, Rocky Mountain species at Fort Carson occur at their eastern and low elevation extreme. The pinyon-juniper woodlands of the foothills reach their northernmost limit in the Fort Carson/Colorado Springs area. Many of these species are more susceptible to disturbance when they occur at the fringe of their range.

Perennial grasses dominate most of Fort Carson's lands. When crushed and compacted by military traffic, these perennials tend to be replaced by annuals and weedy forbs which are more tolerant of disturbance. However, these grasses and other native flora vary in their resistance to traffic. Table 5 compares the resistance of various native species.[70]

A Spring 1980 Soil Conservation Service mapping of the installation rangelands' condition class indicated that most of the ranges were in fair to poor condition. (These condition classes are based on the presence of plants which are climax for the range site. Fair condition has 26 to 50 percent climax plants present; poor condition has 0 to 25 percent.) Both training activities and previous grazing have produced this severe range degradation.

The species abundant on impacted sites include several weedy and non-climax plants. Among these are many Eurasian invaders, such as Russian thistle, cheatgrass, common mullein, black medic, and woolly yarrow, as well as native weeds, such as sunflowers, mustards, and buffalobur. These and other non-climax species, which are able to survive because of their tolerance to disturbance, give some protection to disturbed sites that would otherwise be

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[69] Fort Carson, Land Use and Management Plan (Fort Carson, 1977), p vi.
[70] Roy Cormack, Spring 1980 Fort Carson Survey (Soil Conservation Service).

Table 5

Comparative Resistance of Plants to Repeated, Moderately Heavy Traffic

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|---|---|
| Strong | Saltgrass, Buffalograss, Kentucky bluegrass, Blue grama, Western wheatgrass, sleepygrass, Galleta, Prairie sandreed, sand blues, vine-mesquite hairy goldaster, lemon scurfpea, mouse-ear povertyweed, low phlox, scarlet globemallow, skeletonplant, stemless goldenweed, yarrow, fringed sagebrush, Oregon grape, prickly pear. |
| Moderate | Alkali sacaton, crested wheatgrass, Canada, wild-rye, little bluestem, sideoats grams, needle-and-thread, New Mexican feathergrass, red threeawn, Sandberg bluegrass, sand dropseed, astors, fleabanes, groundsel. |
| Weak | Big bluestem, squirreltail, green needlegrass, Indian grass, Indian ricegrass, Junegrass, mountain muhly, mutton grass, most perennial forbs, and all other trees and shrubs not listed above. |

barren. But generally, these nonclimax species are annuals with relatively limited root systems that do not have the soil-holding ability of the perennial native grasses. Thus, erosion is increased on fair- and poor-condition rangelands, even when there is a surviving vegetative cover.

The pinyon-juniper woodlands at Fort Carson provide the best conditions for maneuver activities. The mature individual trees are often spaced widely enough that vehicles can maneuver between and among them. When these woodlands occur on slopes moderate enough to allow vehicle traffic, the trees provide cover and protection and the slopes provide desirable viewing and firing positions. A similar pattern of use has developed in the cedar-oak woodlands at Fort Hood, since this woodland type generally occurs on hill slopes.

At Fort Carson, vehicles crush understory vegetation and tree seedlings, sideswipe branches and trunks, and damage the roots of mature trees. These types of mechanical destruction are typical of vehicle maneuvering in wooded areas. At Fort Carson, however, the pinyon and juniper are growing in low-moisture conditions at the northern extent of their range. Their annual growth is very small. Thus, replacement of damaged or destroyed trees may require 100 to 150 years under ideal soil and moisture conditions. In addition, compacted soils decrease seedling germination, and sheet and rill erosion increase on denuded slopes.

There are particular problems involved in sensitizing troops to training in a semi-arid environment.[71] Many troops assigned to Fort Carson have previously trained at more mesic installations, particularly in the southeast. The pinyon-juniper woodlands at Fort Carson bear some visual resemblance to the pine-oak woodlands of the southeast (or the cedar-oak woodlands of Fort Hood); however, pinyons and junipers grow much more slowly and are more difficult to replace than the pines, cedars, and oaks at lower elevations in more moist conditions to the east. The average duty assignment at Fort Carson is brief, but efforts are being made to educate troops about the value and fragility of foothill woodlands. Drivers are discouraged from vehicle contact with trees; tank and truck crews are discouraged from using branches and limbs for camouflage.

Because this installation receives such intensive use, and because the woodlands and grasslands have been so severely degraded, there is an extensive program of restoration and enhancement at Fort Carson. In Spring 1980, numerous plots on the post had been pitted, ripped, and/or seeded. There were also many sediment- and erosion-control projects as well as wildlife enhancement projects. Grazing had been discontinued, and large areas had been set aside or restricted for restoration. Furthermore, the Soil Conservation Service was mapping range conditions to assess erosion, sediment control, and rangeland restoration activities. These projects have improved ecological conditions at Fort Carson.[72]

Fort Hood

An intensive investigation of tracked vehicle effects on Fort Hood biota was conducted in the spring of 1978.[73] It was found that training activities in the test area have damaged vegetation considerably. Intensive tracked vehicle activity on any site at Fort Hood for a number of years reduces total plant cover by about 60 percent. The basis of this estimate was that the control area had 59 percent more plant cover than the test area. The greatest effect of training activities on woody plants seems to be a simple reduction of density and cover without any major shifts in species composition. The principal effect of the activities on herbaceous plants is a major shift in species composition from relatively large perennials to small annuals. The small annual plants have an advantage in disturbed conditions because they complete their life cycle within a few months and thus have a better chance of reproducing before being destroyed.

Continuing training activities at the current level will probably not cause much more deterioration unless little used areas are more intensively developed. Travel along the trail networks seems to have stabilized; few new trails have been formed during the past few years. Although there has been some recent damage to woody vegetation, it has been relatively small.

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[71] Personal communication between W. D. Goran (CERL) and COL Waller (G-3, 4th Infantry Division, Fort Carson, CO), 1980.

[72] Fort Carson, Land Use and Management Plan (Fort Carson, 1977), p vi.

[73] W. D. Severinghaus, W. D. Goran, G. D. Schnell, and F. L. Johnson, Effects of Tactical Vehicle Activity on the Mammals, Birds, and Vegetation at Fort Hood, TX, Technical Report N-113/ADA109646 (CERL, 1981).

## Fort Irwin

The blowing sands of the Tularoosa Basin in the Chihauhuan Desert at Fort Bliss can mask signs of cross-country tracked vehicle activity within a few days or even hours. But in the Mohave Desert, where Fort Irwin is located, the lighter surface particles have been eroded, and the desert floor is a crust of small gravels. Tracks from tank and jeep maneuvers of General Patton's troops in the 1940s are still clearly visible on this crust today, more than 35 years later.[74]

Maneuvering at Fort Irwin occurs on shrubland vegetation zones. Creosote bush dominates 85 percent of the landscape -- almost every topographic condition except the higher mountain slopes and the dry lake beds. Drivers frequently pass over creosote bush, crushing branches and damaging root systems. This pattern of driving was also apparent from studies of ORV traffic on the Mohave Desert. "The ORV-used sites had lower shrub counts than control (non-impacted sites). Shrubs are disrupted directly by ORV activities and the removal of the branches for firewood by ORV riders."[75] The creosote bush is usually the tallest and most extensive vegetation on the Mohave Desert landscape, but its individual branches are thin and relatively widely spaced; therefore, it has little resistance to the force of overriding vehicles. However, when crushed, these shrubs appear resilient. On several heavily impacted sites, many of the crushed creosote shrubs were sprouting new shoots and appeared to be recovering.

Bur sage (or burroweed), which is frequently co-dominant with creosote bush, is perhaps somewhat more resistant to vehicle damage. At an intensively used site, bur sage was the dominant persisting shrub, although it provided little actual ground cover. Wilshire[76] suggested that the resistance of this shrub to impact (from ORVs) was due partly to its low, dense form and the relative flexibility of its stems.[77]

At Fort Irwin, the general reduction in vegetative density (both shrub and herbaceous species) corresponded roughly to the level of military use. However, sites with little or moderate use showed almost no decrease in vegetation. Reduced density was most obvious at a site with 67 percent impact, where there were only a few, scattered shrubs. However, this site was not typical of impacted sites; Fort Irwin's environmental impact statement indicates that tracked vehicle turning and climbing exercises are done here.

Generally, a decrease in shrub density and individual shrub canopy was more evident than a decrease in species diversity. Impacted sites had surprisingly diverse flora, including many annual forbs. At these sites, surviving shrubs appeared to provide protective micro-conditions in which both

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[74] H. G. Wilshire and J. K. Nata, "Off-Road Vehicle Effects on California's Mojave Desert," California Biology (California Division of Mines and Geology, 1976), p 1130.

[75] R. B. Bury, R. A. Luckenback, S. D. Busack, Effects of Off-Road Vehicles on the Vertebrates in the California Desert, Wildlife Report 8 (U.S. Fish and Wildlife Service, 1977), p 16.

[76] Wilshire and Nate, 1976, p 122.

[77] Land Use and Management Plan for Fort Carson, Colorado (Dames and Moore, 1977), p vi.

herbaceous plants and small animals persisted. However, at highhighly impacted sites where the surviving shrubs were few and reduced in size, there was no herbaceous vegetation. Even in this area of great impact, there were likely many surviving herbaceous (and shrub) seeds, but the compacted soils inhibit seed germination, while the lack of shrub canopy reduced the chances of seedling survival.

At most installations where wheeled and tracked vehicle activities are conducted, there is a significant increase in weedy species, especially exotics. However, at Fort Irwin, there was relatively little evidence of an invasion of weedy species. Very few of the species collected were either weeds or exotics (e.g., cheatgrass, garden-rocket, tansy-mustard). The native vegetation on the Mohave Desert is adapted to extremely arid conditions (1.5 in. [38.1 mm] average precipitation per year); few weeds and exotics can tolerate such aridity. Furthermore, the soil compaction, increased erosion, and increasingly xeric conditions on impacted sites which discourage native herbaceous species may also discourage weedy, exotic species.

## Fort Knox

The following is a summary of an intensive biota survey done in 1978.[78] Predominant herb cover in the disturbed areas at Fort Knox is camphor weed and white sweet-clover; in the slightly older areas, it is woody vines, especially poison ivy, Virginia creeper, trailing blackberry, and cinquefoil. Korean lespedeza was abundant throughout the disturbed area, apparently having been seeded for soil protection. Many of the less disturbed depressions support a pond or wet habitat; these may be important refuges for birds, deer, and other area wildlife. Three communities were noted in the long-term use area. Depressions support a diverse oak-sassafras-hickory community. Many older tree species characteristic of relatively undisturbed woodlands were present, along with disturbed-site species such as sassafras, sumac, cottonwood, and willow. A white sweet-clover/shrub community occupies upland areas that have been relatively undisturbed for 3 or more years (based on ages of shrubs). Shrubs were mostly sassafras and persimmon. White sweet-clover and lespedeza were common, and ground cover was nearly complete. The camphor-lespedeza community (the least community) occurred in all remaining areas. There were few woody areas here; the soil was heavily disturbed and compacted.

Prior to recent clearing, the short-term use area was a diverse forest of mixed oak and tulip poplar; old field openings are dominated by eastern red cedar, sassafras, and persimmon. Several ridges had apparently been cleared for agriculture and abandoned about 30 to 50 years ago. The forested area had been intensively cut over and opened 35 to 40 years ago; canopy closure occurred about 15 to 20 years ago. Most trees remaining after the most recent clearing are 40 to 75 years old. Older trees were absent, except for a few in clearings; this supports the assumption that the present forest began early in this century, probably on ground previously used for agriculture.

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[78] W. D. Severinghaus, R. E. Riggins, and W. D. Goran, Effects of Tracked Vehicle Activity on Terrestrial Mammals, Birds, and Vegetation at Fort Knox, KY, Special Report N-77/ADA073782 (CERL, 1979).

Most of the control area had been cleared for agricultural use in the past and permitted to revert to forest. However, one small area supported old-growth forest without evidence of disturbance. Eight other communities were noted; each represents a unique set of biotic and abiotic conditions. These all appeared to be the result of reforesting lands cleared for cultivation, pasture, or both. Eastern red cedar persisted in all but two communities and dominated in three communities. Oaks, especially shingle oak, white oak, black oak, and hickories, were important in all communities. Oaks and hickories dominated on upland sites, and maple and tulip poplar were among the more important on mesic sites. Tree reproduction was sparse or absent in both the old-growth forest community and the oak-hickory-dominated community. Reproduction was good in all other communities, especially sugar maple. Flowering dogwood was the most common understory tree in most communities, followed by sugar maple.

Historically, the study sites are similar; all were disturbed by logging, agriculture, and possible Army use. The long-term site has constantly been disturbed for at least 13 years (as revealed by shrub ages). Perennial species which require more time than others to establish and reproduce have been nearly eliminated in much of the long-term area and along the more traveled tracked vehicle roads in the short-term and control areas. Annual opportunist species are favored in these high-risk areas. These plants reproduce, set, and disseminate seed in 2 or 3 months; the seeds, which are often long-lived in the soil, are relatively invulnerable.

Gullies in the long-term area were seasonally devoid of vegetation and very unstable, with continually changing substrates.

Depression communities were actively filling with outwash from the more heavily used areas. If this continues, associated aquatic and riparian vegetation may be eliminated; this will reduce plant species richness and inevitably eliminate organisms associated with these plants.

The short-term area had the richest herb flora of the three study sites. This probably occurred both because disturbances established weedy species and because many species present before the disturbance persisted.

Tank training site preparation involved clearing all woody vegetation of less than 8 cm DBH. This had many side effects. The remaining trees were often damaged during the clearing process. Nearly 80 percent of the remaining trees had limb, trunk, and root wounds caused either by the clearing machinery or from vegetation which fell against them during clearing. Most wounds were quite severe; some of the damaged trees showed upper branch die-back only 6 months after the land was cleared. When this occurs, disease organisms can enter and infect the tree and may kill it. Failing root systems caused by damage from both the initial clearing and later tracked vehicle training may also kill the tree. The short-term area may become much like the long-term area; the regression rate will depend on how often and how much the site is used for training.

Loss of remaining trees and use by tracked vehicles may remove persisting woodland herb species. This herbaceous layer depends on the ameliorating effects of a tree canopy, deciduous leaf litter, shade, rich soils, and other tree-related properties. Much of this reduction in the richness of herbs would occur simply because of site preparation and would be increased by tracked vehicle training.

As shown by the control area, if the short-term site is left fallow in its present condition, the forest canopy may take 100 years or more to close again; the site may take even longer to stabilize. During this time, some of the more common native plant species will become established again, although Eurasian plant species such as the Japanese honeysuckle may become so well established that native species are excluded. This trend was evident in the old-field deciduous section and in sections of the old-field cedar and riparian communities in the control area.

## Fort Lewis

Two prairies on Fort Lewis were studied:[79] the 13th Division Prairie and the Johnson Prairie. These prairies were once probably quite similar in geology, biota, and use by humans. However, the 13th Division Prairie is now much more disturbed than Johnson Prairie. The differences are due to tracked vehicle training maneuvers.

In the Johnson Prairie, total cover of introduced species is 64.5 percent. Cover of native vascular plants is 56.6 percent and is 41.3 percent for non-vascular plants. In contrast, on the 13th Division Prairie, mean cover of introduced species is 49.9 percent; mean cover of vascular natives is 15.5 percent and of non-vascular natives, 57.0 percent. Thus, introduced species occupy much more of the 13th Division Prairie than native vascular plants. Maneuvers do not adversely affect the nonvascular plants on this site as a group, but lichens are absent. Species such as *Festuca*, *Carex*, and *Camassia* are present, but drastically reduced from their dominance on Johnson Prairie and in less disturbed prairies such as the Mima Mounds. The absence of *Cladonia*, a lichen extremely sensitive to trampling or motorized disturbance during the dry season, suggests that the 13th Division Prairie has been disturbed. In contrast, the mosses readily recover from disturbance and are not destroyed by a few episodes of trampling; also, they do not have to compete with introduced species which may occupy their ecological niche.

The cover data from both prairies were combined to determine directly the affinities between the two prairies. Species which occurred only once were deleted to make interpretation easier. The main distinctions between the two prairies were readily seen. *Aster curtus*, *Cladonia*, *Danthonia*, *Trifolium procumbens*, *Lomatium utriculatum*, *Ranunculus californicus*, *Veronica* sp., and *Crepis* occur only on the Johnson Prairie; *Zigadenus*, *Campanula*, *Viola*, Moss sp. (13th Division Prairie #20), and *Taraxacum* occur on the 13th Division Prairie. The 13th Division Prairie is dominated by generalist species common on the Johnson Prairie; however, there are fewer numbers of Johnson Prairie dominants in the 13th Division Prairie. This also favors the argument that the 13th Division Prairie is more disturbed than Johnson Prairie, has suffered substantial reductions in species, biomass, cover, and breadth, and is more dominated by weeds.

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[79] W. D. Severinghaus, R. E. Riggins, and W. D. Goran, "Effects of Tracked Vehicle Activity on Terrestrial Mammals and Birds at Fort Knox, Kentucky," *Trans. Kent. Acad. Sci.* (1980), 41 (1-2); pp 15-26.

Fort Polk

There is both observed and measured evidence of tracked vehicle training impacts on trees on Peason Ridge, Fort Polk. Observed evidence includes:

1. Areas of bared ground, without seedlings, criss-crossed by vehicle tracks and scarred by vehicle-dug pits.

2. A reduction of vegetation at the ground, shrub, and tree levels.

3. Trees bent, twisted, and scarred by direct vehicle impact.

4. Trees fallen or standing dead or partially dead, apparently because of root damage caused by repeated vehicle passings near them.

Measured evidence is as follows:

1. There were fewer trees in test areas than in control areas.

Total actual measured trees: 244 control vs. 193 test.

Computed trees per hectare: 193 control vs. 100.5 test.

2. Of the trees 2 in. (50.8 mm) or more in diameter, more were found on the control grid than on the test grid. In the 0 to .2 sq ft (.018 $m^2$) basal area category, 53.5 percent were control grid trees and 40.4 percent were test grid trees.

3. Tree growth was greater on test sites than on control sites.

Mean growth of all pines: 6.0 mm/year on control sites vs. 7.4 mm/year on test sites.

*Impact on Trees*

Since these grid sites were populated by natural means, seed sources, seed germinating conditions, and the proportional distribution of species varied among sites. The proportional distribution of the various tree species on the test sites prior to tracked vehicle impact was not known; therefore, it was not possible to statistically compare the impact of training activities among the various tree species.

In this mixed pine/oak woodlands, observations suggest that pines, especially longleaf, suffer more from training activities than oak. After a several-year period of aboveground dormancy, the longleaf pine grows rapidly with minimal branching. These polelike seedlings are easily twisted, bent, and trampled by tracked vehicles. Since they provide only minor obstruction to vehicles, drivers do not try to avoid them. On the other hand, young oaks often grow in protected sites, such as beneath full branching mature oaks or near fallen logs, where they are less susceptible to tank damage. Also, drivers make more effort to avoid young oaks.

Longleaf seedings, are only susceptible to damage from grass fires for a short time in their growing cycle; this factor favors them in this region.

However, tracked vehicle traffic reduces ground cover, which reduces the likelihood of spreading ground fires; this decreases the fire-adaptive advantage of longleaf.

Years of continuous training at a particular site may favor oaks; areas which had tall pines and grass understories before training began may eventually be characterized by oak thickets and expanses of bare and sparsely covered ground.

*Rate of Impact*

While training activities in a particular area damage or destroy specific trees, especially young ones, growth data indicate that unimpacted trees continue to grow and presumably continue to produce viable seeds. As long as some trees on a site remain healthy, they will represent a continuous reseeding source. However, persistent training activities keep the ground disturbed, injure and kill seedlings, and eventually affect mature trees by repeatedly damaging roots and occasionally colliding with them. Logically, the longer training activities occur, the more sparse the population of healthy trees will be. However, there is little historical evidence of training activities on Peason Ridge; it is therefore hard to determine actual impact rates.

To determine impact rate at Fort Polk, all four grids were assumed to be of nearly equal density before training activities affected the two test grids; it was also assumed that the impact on the test grids occurred only between 1974 and 1977, when the 5th Infantry (Mechanized) was assigned to Fort Polk. Data indicate that tree population dropped during this time from 193 trees per hectare on control sites to 100.5 trees per hectare on test sites. This is nearly a 50-percent loss of trees in a 3-year period.

A 1968 black and white mosaic imagery enlarged to a 1:5000 scale was used to discern previous tree density on the grid sites. From these photos, it appears that minor vehicle activity had already occurred on the test grids in 1968. There was also evidence from aerial photos that one of the test grids was much denser than any others. If that grid was naturally more dense than the other three, the figure for density reduction (nearly 50 percent) is exaggerated. Also, the impact of training activities may have been spread out over much more than 3 years. While there is not enough information to determine impact rates, the comparative figures for basal area profiles and growth should still be accurate.

## Fort Riley

The rolling, tall grasslands at Fort Riley have received increasingly intense military use. Recently, troops returning from Korea have added to the troop strength and increased the training pressures on the available land. Fort Riley was visited in autumn 1977 and in spring 1980. During those 2-1/2 years, a dramatic increase in cross-country training activity was evident.

This can be attributed to increasing troop strength and to a change in training procedures.[80] In 1977, much of the tracked vehicle traffic was confined to the tank trails. In 1980, vehicle units which left the cantonment area were considered "tactical," although many tracked vehicles still moved along the main tank trails.

The movement of tracked vehicles, both along established roads and trails and cross-country, presents significant environmental problems. At Fort Riley, these problems are intensified. The tables from which the tanks practice firing are at a maximum on-post distance from the cantonment area. Thus, the trails between the cantonment area and these tables receive intensive use (which is especially damaging during wet conditions) and often need smoothing and grading. All the on-post trails suffer from poor drainage, rutting, and erosion, especially on slopes. With intensive use, they eventually become impassable. To avoid impassable areas, drivers make new paths adjacent to the existing trails. Thus, the major trails become bands of ruts and weedy forbs 50 to 100 m wide.

Tank trails at Riley and other FORSCOM posts are not considered "real property." Thus, it is hard for the Facility Engineer to allocate funds for culverts and for grading and surfacing these trails. The Army is re-evaluating this situation; however, in the past, many tank trail improvements were done by engineering units as training exercises.

Because of the soil density, the frequency of high soil-moisture conditions, and the distance of firing facilities from cantonment areas, the problems of tracked vehicle movement along established corridors have increased at Fort Riley. Similar problems occur at most installations where tracked vehicle training occurs; however, occasional improvements by engineering units are seldom enough.

The impacts of tracked vehicle traffic on Fort Riley's tall grasses are similar to the impacts on the short and medium grasses at Fort Carson. Repeated crushings by overpassing vehicles (or shearings by turning vehicles) destroy the native perennials, such as big bluestem, switchgrass, little bluestem, Indian grass, and grama grasses; they are replaced by weedy forbs, such as curly dock, common mullein, tansy mustard, black medic, field bindweed, and various species of sunflowers and goldenrods.

In the tall grasslands, the mechanical pressure of cross-country vehicles often breaks the matt of grass roots; this allows woody plants, such as Eastern red cedar, buckbrush, and rough-leveled dogwood, to expand out onto the prairies. Thus, military training activities at Fort Riley have decreased grasslands and increased shrublands and woodlands. However, the post's current program of burning grasslands not only reduces fire danger and improves habitat for some species, but also helps preserve the tall prairie grasslands against further invasion by woody species.

[80]Personal communication between W. D. Goran (CERL) and Arnold Bowman (Chief of Range Control, Fort Riley, Kansas), 1977-1980.

## Fort Stewart

Because Fort Stewart is on flat land which contains a great deal of moisture, only a small percent of the land will support heavy vehicle movement. Also, the flat terrain limits the types of tactical activities that can be done on the installation. However, this land will be increasingly stressed as the number of tracked vehicles used increases.

The land's flatness and high moisture content allow vegetative regrowth; dense vegetation, in turn, protects the soil from erosion. However, tracked vehicle training on wetlands can destroy and remove this cover; this results in depressions that erode and scar the land for several years.

## 7 RESULTS OF SOIL DATA COLLECTION

### Summary of Conditions

A major impact of cross-country vehicle movement on Army lands is soil compaction, which is a decrease in the volume of pore spaces in the soil. This can decrease both the soil's water-holding capacity and water's ability to move into and through it. If water infiltration decreases, water run-off will increase. Vehicle traffic also tends to smooth the ground surface so there is less resistance to surface flow. Increased run-off and more rapid surface flow can contribute to increased erosion and subsequent sedimentation; if large areas are affected, it can increase the possibility of flash floods.

Studying the effects of off-road motorcycle traffic on the Mohave Desert, Wilshire summarized, "Soil compaction is the dominant consequence of motorcycle use. Combined with the fact that vehicle use had denuded the surfaces of much plant cover and has stripped the protective desert pavement, motorcycle use has caused a significant increase in the potential for erosion."[87]

Soil compaction also significantly affects vegetation. Decreased pore space can limit root penetration and seed germination. If compaction reduces a soil's water-holding capacity, plants will have less water. Compaction can also reduce a plant's root strength and penetrating ability. Reduced infiltration may also cause problems with standing water and inadequate aeration. In the EIS for the National Training Center, Fort Irwin Site, it is concluded that "the most serious and widespread effects on vegetation appear to result from soil compaction. Impacts of soil compaction on vegetation must be considered long-term or even permanent, with recovery, if at all possible, requiring several decades of non-use."[82]

Generally, the degree of soil compaction varies in proportion to the level of traffic (surface pressure). Compaction may only be slight if a vehicle passes straight across an area only one time; however, repeated passes in the same area may cause relatively permanent damage. While natural weathering processes, such as freezing and thawing and renewed root growth can eventually restore the structure of compacted soil, continued use of compacted areas only increases problems.

The level of compaction relates proportionally to the level of surface energy applied; however, the degree to which the soil is damaged relates to the characteristics of the original soil. Soils with a mixture of particle sizes are most susceptible to damage. Within a soil, the loss of macro-pore space most affects the movement of water and air.

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[87]W. D. Severinghaus and W. D. Goran, "Notes on the Distribution and Ecology of Some Birds and Mammals in Central, Texas," Texas Jour. Sci. (1982).
[82]EIS for the National Training Center (Fort Irwin, 1979), p B-17.

## Fort Benning

Tracked vehicle traffic at Fort Benning has increased the already rapid pace of natural erosion, especially gully erosion, in areas of steep slopes and loosely consolidated, sandy soils. Frequent areas of sheet and gully erosion were quite evident near Bush Hill. Tracked vehicle traffic has also resulted in loss of vegetation and reverse succession (retrogression) on many sites. However, most of these areas were previously degraded by lumbering, fire, and/or agricultural use. Compaction is not a significant problem on the well-drained, coarse-grained soils.

## Fort Bliss

In the coarse-grained, porous soils of the Tularoosa Basin, soil compaction (or density) on unimpacted sites could be measured only with an adapter foot, an attachment to the penetrometer which increases the ground contacting surface area 16 times. Readings at unimpacted sites averaged 0.15 tons of pressure per square foot of surface.* Readings taken in single-pass tracked vehicle paths increased compaction 15 times, to 2.25; average readings on multiple-pass tracks were only slightly higher -- 3.0.

Because the soils in the Tularoosa Basin are so coarse-grained, deep, and porous, it is not clear that the increases in compaction resulting from vehicle traffic will inhibit plant growth or increase run-off, except in areas of intense traffic, such as along roads. However, other soils, such as those on the Otera Mesa on Fort Bliss, are more susceptible to compaction. However, soil loss from wind erosion is a major problem in the dune area, especially at sites where the stabilizing shrubs are disturbed.

## Fort Carson

Soil compaction readings were obtained from four sites; however, comparative readings varied widely, with differences in parent material, soil depth, soil texture, and structure.

Readings were also taken in a creekbed, where soils were much denser than in surrounding soil. Unimpacted readings in the creekbed averaged 1.2; readings in a trail passing across this creekbed jumped to 4.0, an increase of 233 percent.

Slope measurements on impacted sites showed increases in soil density because of vehicle traffic, with the greatest increases on areas receiving repeated vehicle use. At one site, the single-pass density increase was 26 percent, the multiple-pass density increase was 55 percent, and the tank trail density increase was more than 60 percent. At another site there was no density increase on single-pass sites, a 33 percent density increase in multiple-pass tracks, and a 67 percent density increase along tank trails. It

* All readings are in units of tons of pressure per square foot of ground. However, since these measurements are imprecise, their relative value is more important than their absolute value. The unit expression is therefore usually dropped.

appears that single-pass traffic generally caused only moderate compaction in comparison to the compaction resulting from repeated and/or continuous traffic.

## Fort Hood

Soils at Fort Hood are thin and gravelly, even on completely undisturbed sites. The bedrock is very close to the surface; this prevents the formation of deep gullies. The thin layer of topsoil is washed away soon after a vehicle trail is established. However, sediment transport is minimal because there is very little soil to erode; however, even minimal loss is serious because of the limited soil depth.

Penetrometer readings from both control test sites showed high variance in both areas, with a range in both stands of 0.25 to 4.5 kg/cm$^2$. However, the means were different enough to be statistically significant ($P<.005$). The mean of all penetrometer readings in the control area was 1.19 kg/cm$^2$, while the mean for the TTA was 2.95 kg/cm$^2$. An attempt was made to determine the soil's recovery rate from compaction; recognizable tank tracks were divided into "new" (no vegetation) and "old" (vegetation beginning to recover). The mean penetrometer reading on "new" tracks was 3.51 kg/cm$^2$, and the mean on "old tracks was 2.80 kg/cm$^2$. However, the variance was quite high, and the difference was not statistically significant.

## Fort Irwin

Penetrometer readings taken from three sites showed an overall density increase of 84 percent on impacted soils versus unimpacted sites. For these measurements, distinctions were not made between single- and multiple-vehicle passes; however, on one site, measurements were made in a berm created by a vehicle turn. These berms were described in the 1978 Joint Environmental Impact Assessment (EIA) for Fort Irwin. "Field investigations showed that when wheeled or tracked vehicles make sharp turns, soil was thrown up to the outside of the tracks. Such 'berms' often measured 4 inches high in the old tracks."[83] These vehicle turns typically break through the protective desert pavement (a residual layer of coarse particles resistant to erosion), displacing the finer-grained, underlying soils and shearing off any plants in their turning path. At this site, average density measurements in this displaced material were 60 percent less than on unimpacted soils.

Density measurements with a more sophisticated penetrometer were made for the 1978 Joint EIA in a study area where there had been little or no activity for the previous 11 years. "Measurements of soil density in the study area demonstrated compaction still evident after 11 years of non-use...Roads attributed to these (previous) exercises showed minimal density increases of

[83] Environmental Impact Assessment for Fort Irwin, CA (Headquarters, Reserve Components, Training Center, California National Guard, Fort Irwin, CA, 1978).

21 to 44 percent with a hard packed layer averaging 3-1/2 inches below the surface."[84]

## Fort Knox

The major impacts of tracked vehicle training activities on Army lands appear to be disturbance of the soil surface by the compacting and scraping activities of clearing, and the soil compaction, vegetative disturbance, and resulting erosion caused by training. Compaction leads to a loss of soil structure, especially when the soil is wet. Erosion causes loss of soil fertility. Ultimately, such soil damage would lead to a totally barren landscape on which few species could survive even if disturbances were stopped.

One result of clearing and continued heavy use of tracked vehicles in long-term use areas is extensive sheet erosion and local, severe gully erosion. The site studied was open, with widely scattered weedy herbs and grasses. Sprouts of persimmon and sassafras up to 2 and 3 m high were present throughout, usually in small areas where tracked vehicle use was infrequent. Most of the original soil profile was absent or disturbed, and chert fragments were abundant. In depressions and draws, especially those with less disturbed vegetation, soil deposition was pronounced. Trees, especially oak, hickory, sassafras, cottonwood, and willow were present in many of these depressions.

Soils of the areas studied are naturally compact and have suffered considerable erosion because of past agricultural practices. Where vegetation is removed, especially on slopes greater than 6 percent, continued erosion soon eliminates the small amount of topsoil that has collected since the soils were fallowed from agricultural use. Removal of vegetation and use of heavy, tracked vehicles compounds this problem, because soils become more compacted. As a result, infiltration is reduced, loss of organic material and litter decreases the population of animals that otherwise would increase soil porosity, and disturbance prevents establishment of protective vegetative cover.

The initial impact of tracked vehicle travel on soil compaction was evident. Soil penetrometer measurements were taken in recent vehicle tracks of all community types at the short-term site. The mean compaction value from these measurements was much greater than the mean values of all other community types except the open weedy community.

Vehicles scrape the upper few inches of soil into a loose duff and, at the same time, compress the lower horizons. Less water infiltrates, and instead, more easily removes the loosened soil at the surface. Compaction, with the resultant loss of soil structure and fertility, then occurs. Such damage would heal naturally only during successional processes spanning perhaps 1000 or more years. During this time of soil development, vegetation would resemble the sparse, weedy communities now present in nearby areas that have suffered similar disruption.

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[84]Environmental Impact Assessment for Fort Irwin, CA (Headquarters, Reserve Components Training Center, California National Guard, Fort Irwin, CA, 1978).

## Fort Lewis

Soil damage at Fort Lewis was most evident in the creekbed areas, where vehicles crossed water-saturated areas and caused damages such as soil deformation and compaction. Soil compaction eliminates many of the invertebrate fauna that are the major food sources of the American robin and common flicker. There was some evidence of soil disturbance on the Johnson Prairie. In contrast, the 13th Division Prairie showed much soil disturbance from tracked vehicles, especially in places of vehicle turns. Weeds replaced native grasses in those places. One apparent effect of soil compaction is the absence of the soil-dwelling Townsend mole on impacted sites.

## Fort Riley

Soils at Riley were generally more dense and fine-grained than at Forts Bliss, Benning, Irwin, and Carson. Density readings in unimpacted soils ranged from 2.5 to 4.0 and were often higher than readings on impacted soils at other installations.

Forest soils were slightly less dense than the prairie soils due to the presence of O (organic) horizons at their surface. However, on both forest and prairie soils, readings in single-pass areas greatly surpassed the calibrated limit of five at all three sites tested.

Measurements were also made in a field which had received continuous traffic use. Except for a few hardy weeds, this field was denuded; both sheet and rill erosion were evident. Density readings from areas where the topsoil had partially eroded were somewhat lower (4.4) than on uneroded, single-pass sites. In the gullies, where much topsoil had washed away, readings decreased to an average of 3.4. Overall, however, soil compaction in this field probably reduced plant cover and increased erosion greatly.

## Fort Stewart

Erosion is only a minor problem at Fort Stewart. Because the land is flat and high moisture results in fast vegetative regrowth, soil losses are minimal. Also, dense vegetation protects the land from wind erosion. However, the flat, wet conditions produce an environment that is generally unsuitable for tracked vehicle training. Only a small percent of the land will support the movement of heavy vehicles. This land will be increasingly stressed as the number of tracked vehicles used increases. Furthermore, the flat terrain limits the types of tactical activities that can be done on the installation.

While there is some evidence of retrogression on upland sites at Fort Stewart, such patterns are relatively insignificant, partly because of the faster rate of regrowth. However, tracked vehicle traffic on wetlands can produce depressions that scar the land for several years.

## 8 OBSERVATIONS AND APPLICATIONS

### Impact Sequence

Impacts from tracked vehicle training activities varied on each of the 12 installations observed. This was to be expected, since the land farms, soils, climates, and native flora and fauna differed on each installation. To a lesser extent, training activities also varied from site to site, yet there was a sequence of impact events that occurred, to a greater or lesser degree, in each region and at each installation. This sequence was:

1. One-time only traffic in an area results in minor disturbance. The first impact is generally light damage to ground surface vegetation. Where tracked vehicles turn, this damage can be locally severe, both to ground vegetation and underlying soils.

2. Occasional disturbance, with accompanying increase in noise and associated troop movement, displaces the most sensitive species. Ground vegetation is further damaged, with the loss of species of low "wear resistance" and the introduction of species with a high tolerance of disturbance. Soils subject to compaction exhibit problems with water percolation and root penetration. Surface losses of soils increase.

3. Frequent, repeated use of an area results in general degradation of flora, fauna, and soils. Trees suffer from vehicle sideswipes and root exposure, and open areas develop in the canopy. Young seedlings do not survive in high traffic areas. Many locally indigenous/sensitive plant and animal species are displaced. Grasses are often replaced by weedy forbs. Loss of surface vegetation results in exposed soil surfaces, although length of surface exposure depends on climatic conditions and vegetative regrowth rates. Loss of canopy and some ground surface vegetation often results in locally more xeric conditions.

Generally, there is an overall biomass decrease of both flora and fauna. However, increases may occur among certain species, such as seed-eating, adaptive, and disturbance-tolerant fauna (e.g., white-footed mice at Knox, Hood, Carson, and Riley) and annual forbs which produce abundant seed harvests (e.g., poor joe at Benning, golden rod and mustard at Riley, Russian thistle at Yakima, Carson, and Bliss).

4. Intense, constant use results in a largely denuded landscape supporting only seasonal populations of disturbance-tolerant flora and fauna. Soil erosion may result in deep gulleys, and areas of underlying parent material may be exposed. Such areas may be very difficult to reclaim.

Those sites on the installations that fall under points 2 and 3 of this sequence should be considered for monitoring and maintenance activities. Areas that receive constant, intense use (Number 4 in the sequence) may have degraded beyond a point for which their ecological integrity could be preserved, but proper maintenance would maintain their use for training and to reduce off-site pollution. On the 12 installations surveyed, only a few sites fall into Number 4 of this sequence. However, numerous sites on all 12 posts are typical of Number 3 in this sequence.

## Objectives

Essentially, there are three major objectives for understanding and minimizing the ecological impacts of tracked vehicle training activities. First, the National Environmental Policy Act of 1969 (NEPA) and Army Regulation 200-2[85] require that the Army minimize any significant short-term and long-term environmental impacts. Thus, the Army is responsible for maintaining the ecological diversity and viability of the lands in its care. Furthermore, any rare and endangered species, and the habitat necessary to maintain them, that occur on Army land are protected by the Rare and Endangered Species Act.

Second, Army training lands are limited, and care and maintenance of these lands is required to keep them usable for training. As new weapon systems have been developed, the Army's training land requirements have increased; likewise, the stress on the existing land base has also increased. However, in the decades since World War II, additions to the existing land-base, have been few. Proposals for additions to installations have sometimes met with opposition. Thus, it is in the Army's interest to maintain the soils and vegetation on current training lands to maintain a realistic training environment and retain trafficable conditions. Without maintenance, lands that receive intense use become devegetated and do not provide sufficient cover for troops and vehicles. Furthermore, gulleying and ponding (due to loss of soil structure and impermeability) and dust cause severe problems for troop and vehicle movement.

Third, degradation of training lands can result in off-site problems, such as increased downstream sediment loads. Increased sediment can degrade aquatic habitats and becomes a problem for all downstream water users. In some areas, blowing sands and/or finer particles can also cause problems for communities and land owners downwind of the training areas.

## Applications

This study of the ecological effects of tracked vehicle training was undertaken to develop a basic understanding of the ecological relationships that result from training impacts. The installation surveys have provided insights into these complex relationshps and have also stimulated the development of some specific monitoring, analysis and predictive tools. These surveys are only the first phase of a long-term program intended to address the three broad objectives to maintain the ecological integrity of Army land, to maintain these lands for tracked vehicle training use, and to minimize on- and off-post impacts that result from tracked vehicle training activities. Other phases of this program are concentrating on monitoring, predictive, and maintenance activities. These result in products that have more immediate applicability to training and environmental land-use planning. A report is

[85] Environmental Quality; Environmental Effects of Army Actions, Army Regulation 200-2 (Department of the Army, November 1980).

now being prepared which investigates a variety of land maintenance techniques and evaluates their applicability to training land maintenance.[86]

While the investigative phase of this program was intended to provide a foundation for subsequent, more-applied phases, some techniques and perspectives developed have immediate applicability. Land managers and installation officials will better be able to understand the impacts that training activities have on various flora and fauna and be able to write and review more informed and analytical impact assessments/statements.

Some of the techniques used in this study can be easily adapted to monitor conditions on the training area. For example, foot-transects on selected training areas can provide a simple means to monitor annual changes in vegetative cover resulting from increases or decreases in training intensities. These transects, which were used to compare levels of impact from one site to another in the installation surveys, can also be used as an indicator technique for maintenance procedures. For example, if a certain predetermined percentage of the ground cover is found to be disturbed as a result of a foot-transect survey of an area, then maintenance activities, such as fertilizing, discing, and seeding, could be initiated. This percent ground cover disturbance threshold would vary from site to site, depending on vegetative regrowth conditions, but the foot-transect monitoring technique should be applicable to most conditions (see Chapter 3).

The foot-transect technique can be done by essentially untrained personnel. The only skill involved is in selecting appropriate sites. Other techniques used in these installation surveys require skilled personnel, but can be adapted into a relatively simple monitoring program. Because of the large number of species that usually occur in a region, birds are a good indicator of a site's ecological condition. Bird transects in selected sites, conducted during the breeding season, can provide valuable information about the diversity of bird species and the total number of individuals present in an area. By using guild theory, the functional roles of these bird species to environmental resources can then be interpreted. Guild theory can also be useful in studying small mammal populations, but the number of mammal species present at any one site is usually less than the number of bird species; thus, bird studies generally prove more useful. Techniques for bird transect surveys are referenced in Chapter 3, pp 28-30.

In addition to employing these research techniques, land managers may also be able to usefully employ some of the information in this report. Most installation ecological resources management has been concentrated on installation-wide activities, aimed at improving conditions for game species. The surveys concentrated on small sites within the installations. Generally, only relatively small areas on-post have been degraded to a point where maintenance activities are required, though somewhat larger areas require monitoring. For most species, and at most installations, game animal populations are higher on-post than off-post. This reflects not only the integrity and variety of on-post habitat, but also the success of wildlife management activities. But these management activities are now conducted on macro-scale

[86] B. Baran, et al., <u>An Overview of Potential Methods for Maintaining Training Area Environments in Arid and Semi-Arid Climates</u>, Technical Report N-139 (CERL, 1983).

(installation-wide) and need to be supplemented with management programs that concentrate on degraded micro-scale sites. Traditional wildlife management techniques, such as seeding and discing food-resource plant species, combined with traditional land-conservation techniques, such as erosion and sediment transport control measures, could help prolong the installation's useful training life and maintain the ecological viability of impacted Army lands.

# 9 CONCLUSIONS

This report has described some of the impacts caused by tracked vehicle training maneuvers on the natural environment. Impacts varied, depending on the installation and ecosystem studied.

Mammal populations show both an overall reduction in biomass (an increase in white-footed mice and a decrease in shrews, voles, moles, squirrels, and chipmunks) and a change in diversity which is mainly evident in terms of species replacement.

Bird populations generally show significant biomass reduction. The concurrent change in diversity is not wholly evident, since numbers of species remain about the same. The important change is in species replacement. In most training areas and ecosystems, species which are secretive or highly sensitive to disturbance are replaced by less sensitive species; many of these are clearly disturbed-site, early successional, or introduced species.

Plant populations are drastically reduced and altered due mainly to: loss during clearing/preparation operations; physical contact with training vehicles, which either kills the plant or causes injury great enough to kill it; and root damage, reduced seed germination, or reduced seedling growth due to soil compaction. Climax species tend to be replaced by early successional species, and, to varying degrees, by a reversal of the successional process.

Soil problems are universal due to increased erosion caused by compaction of the lower horizons, loosening of the upper horizons and duff, and removal of vegetative cover. The extent of these problems varies, depending on factors such as slope, soil type, depth to bedrock, rainfall, and vegetative cover.

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ATTN: SARHO-EN
Indiana 47111
ATTN: SARIO-EN
Iowa 52638
ATTN: SARIO-EN
Kansas City 67357
ATTN: SARKA-FE

Army Ammunition Plants
Lake City 64056
ATTN: SARLC-O-F
Lone Star 75501
ATTN: SARLS-EN
Longhorn 75670
ATTN: SARLO-O
Louisiana 71102
ATTN: SARLA-S
Milan 38358
ATTN: SARMI-EN
Radford 24141
ATTN: SARRA-IE
Volunteer 34701
ATTN: SARVO-O

US Army Medical Bioengineering Res. and Development Laboratory 21701
ATTN: Env. Protection and Res. Div.

Institute for Water Resources 22060
ATTN: J. Delli Priscoli

Director, USA-WES 39181
ATTN: WES-ER

US Naval Academy 21402 (2)

Chief, Naval Operations 20360
ATTN: The Library

Kirtland AFB, NM 87117
ATTN: DE

HQ USAF/LEEEU
WASH DC 20330

Patrick AFB, FL 32925
ATTN: XRQ

Tyndall AFB, FL 32403
ATTNL AFESC/ECA
ATTN: AFESC-TST
ATTN: AFESC/DEV (3)

Dept of Transportation Library 20590

Env. Protection Agency (EPA) 20460 (2)

Federal Aviation Administration 20591
Chief, Construction and Maintenance Standrds Branch, AAS-580

Institute of Defense Analysis
Arlington, VA 22202

Office of Mgmt Svc, MS 110-FAA 20553

Transportation Research Board (3) 20418

Veterans Administration 20420
Environmental Planning Div. (088C)

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